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# WATER QUALITY INVENTORY OF THE SOUTHERN COASTAL PLAIN AND ATLANTIC COAST FLATWOODS OF GEORGIA

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# WATER QUALITY INVENTORY OF THE SOUTHERN COASTAL PLAIN AND ATLANTIC COAST FLATWOODS OF GEORGIA

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## INTRODUCTION

Concern about the quality of our Nation's environment has raised a reasonable question: Is agriculture a significant contributor to water pollution? The question is difficult to answer since there is wide regional variation in agricultural practices. For example, agriculture in the Coastal Plain of Georgia consists of intensively farmed crop, pasture, and forest lands flanking wide flood plains that support hardwood-pine and swamp-hardwood communities. Agriculture in another region may consist of large cattle feedlots. Since agriculture includes such diverse activities, the industry's impact on water quality must be examined by individual activity and area.

To determine the influence of agriculture on water quality in large, complex watersheds, the Agricultural Research Service conducted a survey of streamflow and alluvial ground water in the predominantly agricultural area of the Coastal Plain and adjacent Atlantic Coast Flatwoods of Georgia. The specific objectives of the study were (1) to inventory water quality characteristics associated with agricultural practices, including use of chemical fertilizers, in both surface and shallow subsurface waters, (2) to determine if there is significant difference in the quality of water from rural-agricultural and suburban-urban watersheds, and (3) to determine seasonal changes in the quality of streamflow. The water properties measured in the survey were conductivity, chloride ($Cl^-$) content, total nitrogen (N) and phosphorus (P) contents, chemical oxygen demand (C.O.D.), total iron (Fe) content, and pH. These properties are associated with water quality.

## DESCRIPTION OF SURVEY AREA

The survey was conducted in agricultural and urban drainage areas in an intensively farmed region of the southern Coastal Plain and Atlantic Coast Flatwoods of Georgia (fig. 1). The study area includes cultivated croplands (peanuts, corn, cotton, tobacco, soybeans, and truck crops), pasture, oak-pine forest, pine plantations, orchards, pine-grass communities, hardwood-pine communities, and swamp hardwoods.

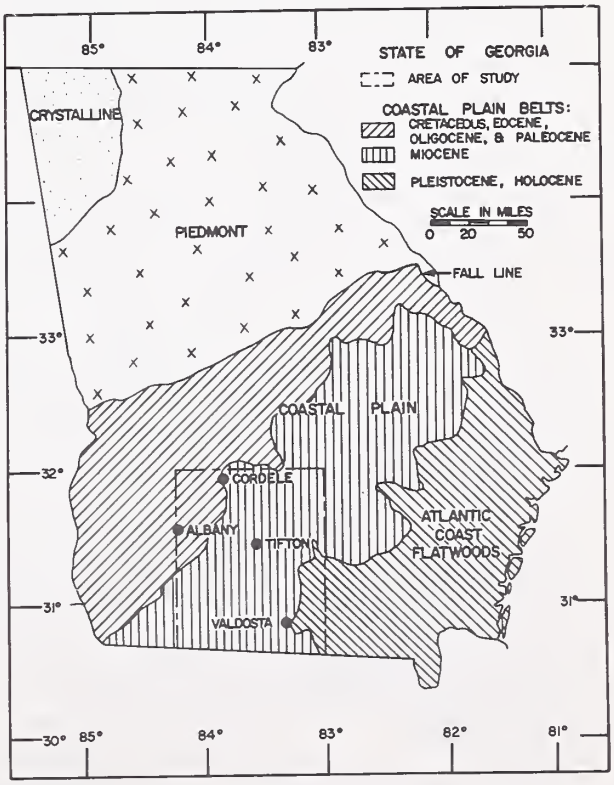


FIGURE 1.—Location map of water quality survey area, showing physiographic and stratigraphic zones.

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The area has generally low topographic relief, with poorly defined stream channels. The uplands are cultivated, while the wide stream valleys consist of hardwood-pine and swamp-hardwood communities.

The sandy soils in this area have high infiltration rates, permitting rainfall to move freely into the soil. These soils are underlain at depths from 3 to 20 feet by semi-impermeable parent material (Miocene Age Hawthorn Formation). This zone of low permeability impedes the downward movement of subsurface water, causing it to move laterally and return as streamflow. This shallow subsurface return flow makes up the major portion of streamflow in the southeastern Coastal Plain. Small plot studies have shown that up to 80 percent of the total discharge is from subsurface flow. Surface runoff occurs only during intense rainfall events.[2]

Except for incised river channels, defined stream channels in the Coastal Plain and Flatwoods are practically nonexistent. Streamflow occurs over broad alluvial valleys covered by relatively dense vegetation. Swamp vegetation in the channels provides a natural filtering system for sediment and associated chemicals. The vegetation in the channel, high soil infiltration rates, and shallow subsurface water movement cause long-duration hydrographs with low peak discharges.

The study area contains a number of small cities, generally with less than 25,000 population. Agriculture is the primary business of the region, and there are a few industries.

The Tifton average annual rainfall for the period 1923–71 was 47.36 inches, with good distribution throughout the year except October and November. Long-term monthly averages from the Georgia Coastal Plain Experiment Station at Tifton are given in table 1. Monthly rainfall for the study period (December 1970–February 1972) is also shown in table 1. Rainfall for the study period exceeded the long-term average by 8.69 inches. However, September was considerably drier than the long-term average.

[2]Rawls, W. J. and Asmussen, L. E. 1973. Subsurface flow in the Georgia Coastal Plain. J. Irrig. Drain. Div., Proc. Am. Soc. Civ. Eng. 99(IR3): 375–385.

TABLE 1.—*Rainfall data, Georgia Coastal Plain Experiment Station, Tifton, Ga.*

[49-year average and monthly rainfall for study period]

| Month | Rainfall (inches) | | | |
|---|---|---|---|---|
| | Average, | Study period[1] | | |
| | 1923–71 | 1970 | 1971 | 1972 |
| January | 3.99 | .... | 2.55 | 5.70 |
| February | 4.00 | .... | 5.22 | 5.58 |
| March | 4.73 | .... | 5.32 | .... |
| April | 4.09 | .... | 3.72 | .... |
| May | 3.51 | .... | 4.79 | .... |
| June | 4.62 | .... | 6.46 | .... |
| July | 6.06 | .... | 7.61 | .... |
| August | 5.25 | .... | 6.16 | .... |
| September | 3.65 | .... | .58 | .... |
| October | 1.93 | .... | 1.82 | .... |
| November | 1.97 | .... | 3.85 | .... |
| December | 3.56 | 3.01 | 5.23 | .... |
| Total | [2]47.36 | 3.01 | 53.31 | 11.28 |

[1] Total rainfall for study period equaled 67.60 inches.

[2] Total rainfall based on long-term (14-month) average equaled 58.91 inches.

## SAMPLING SITES

Watershed streamflow was sampled at 96 locations (fig. 2) in watershed headwater areas, in midstream reaches, and above and below stream confluences. Watersheds were divided into four categories according to population density and agricultural or industrial activity. The four categories are rural-agricultural (A), rural-agricultural with *some* urban influence (B), rural-agricultural with *definite* urban influence (C), and urban-suburban (D). Site location, watershed category, total channel length, watershed area, estimated total population, and average population densities are given in the appendix. There were 44 rural-agricultural watersheds, 12 rural-agricultural watersheds with *some* urban-suburban influence, 17 rural-agricultural watersheds with *definite* urban-suburban influence, and 23 urban-suburban watersheds.

In addition to the complex watersheds, the sample sites included four ponds, one pit storage, and two alluvial ground-water wells. Samples were collected above and below the ponds and from the reservoir storage. Pond and pit sites included mixed-cover, single-cover, and mixed agricultural-urban watersheds. Ground-water wells included an agricultural watershed and an agricultural watershed with some urbanization.

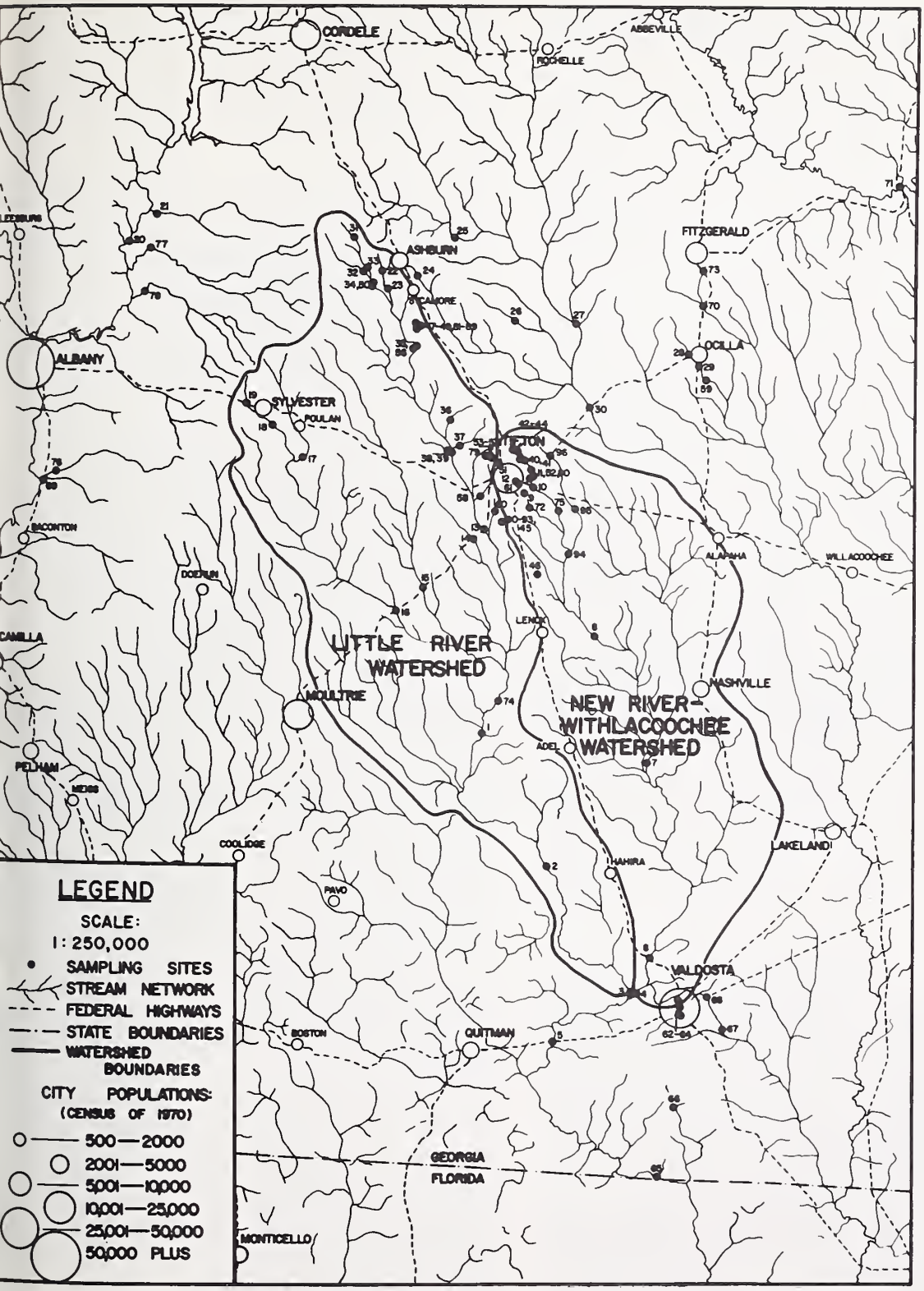


FIGURE 2.—Water sampling sites. The sites are described in the appendix.

Survey watershed areas ranged from less than 1 $mi^2$ to just over 5,000 $mi^2$. There were 57 sites with a drainage area of less than 10 $mi^2$ and 17 with an area greater than 100 $mi^2$.

Channel lengths as determined from 1:250,000 scale maps ranged from less than 1 to 750 miles. Where channel lengths tabulated in the appendix are zero values, channels are not detectable on 1:250,000 scale maps. Streams that do not join the main channel system terminate in swamps or limestone sinks.

Estimated total populations and average population densities (appendix) were computed from 1970 census data. Populations of cities within watershed boundaries were added to the watershed into which treated city sewage is discharged. The population density ranged from 0 to 4,000/$mi^2$. Urban-suburban areas included in this survey were Adel, Albany, Ashburn, Fitzgerald, Nashville, Ocilla, Sylvester, Tifton, and Valdosta. (See fig. 2.) The survey was in no way intended to determine adequacy and inadequacy of city sewage treatment; it merely provided a comparison of water characteristics relative to that of agricultural areas.

Two stream networks within the study area comprised the primary basis for comparison between urban-suburban and rural-agricultural water quality. These were the Little River basin, a rural-agricultural watershed containing little to no urbanization, and the New River-Withlacoochee basin, which drains several small urban (Tifton, Lenox, Nashville, Adel, and Valdosta) and industrial areas (fig. 2).

As the survey progressed, sampling sites were added or deleted as deemed advisable by the investigators to identify source areas. The period of record and frequency of sampling for each site are given in the appendix.

Streamflow was not measured at all locations sampled in the study. Monthly discharge for three sites located on major stream systems is shown in figure 3. These were the only streamflow records in or around the study area. There is little variation in per-unit area discharge among sites even though there is a large variation in size. Low discharge occurred the last 4 months of 1970 and September through November of 1971. The greatest mean daily discharge on the Alapaha River for the study period was recorded in March 1971 (2,161 $ft^3/s$). The highest discharge value at site 35 was in March (184 $ft^3/s$), and the minimum was in November (3.1 $ft^3/s$). The maximum at site 40 was 68 $ft^3/s$ in January 1972, and zero discharge was recorded in October 1971.

Sites were selected to provide a continuum of drainage areas ranging from rural-agricultural areas to urban areas. The survey period, December 1970 through February 1972, included three high-flow periods (1, 2, and 5), one intermediate period (3), and one low-flow period (4) from September to November 1971 (fig. 3). A total of 1,850 samples were collected and analyzed.

## ANALYSIS OF SAMPLES

Depth-integrated samples were collected at each site in 1-pint glass milk bottles with a D–48 sampler either weekly, biweekly, or triweekly. Stagnant water was not sampled. The following laboratory analyses were run on the samples the day after collection if possible; if not, the samples were refrigerated until analysis.

*Conductivity* was determined by a conductivity bridge (cell constant = 0.1) directly on the field sample.

*Chloride* ($Cl^-$) content was determined by potentiometric titration with silver nitrate solution, using a glass and silver-silver chloride electrode system.[3]

*Total nitrogen* (N). The samples were digested to fumes with concentrated sulfuric acid, neutralized with sodium hydroxide, and treated with Nessler's reagent, which produces a graduated series of colors from yellow to brown.[4] Concentrations were determined colorimetrically, and the lowest level detectable was 0.5 part per million (p/m).

*Total phosphorus* (P) includes all soluble orthophosphates and polyphosphates, insoluble phosphorus, and organic phosphorus. The phosphates were converted to orthophosphate form by sulfuric acid hydrolysis. This complex was reduced to a blue-colored complex by the combined reagent method (ascorbic acid, sulfuric acid, potassium antimonyl tartrate, and am-

[3]American Public Health Association, Inc. 1965. Standard methods for the examination of water and wastewater. Ed. 12, pp. 372–374. New York.

[4]Ibid., pp. 193–194.

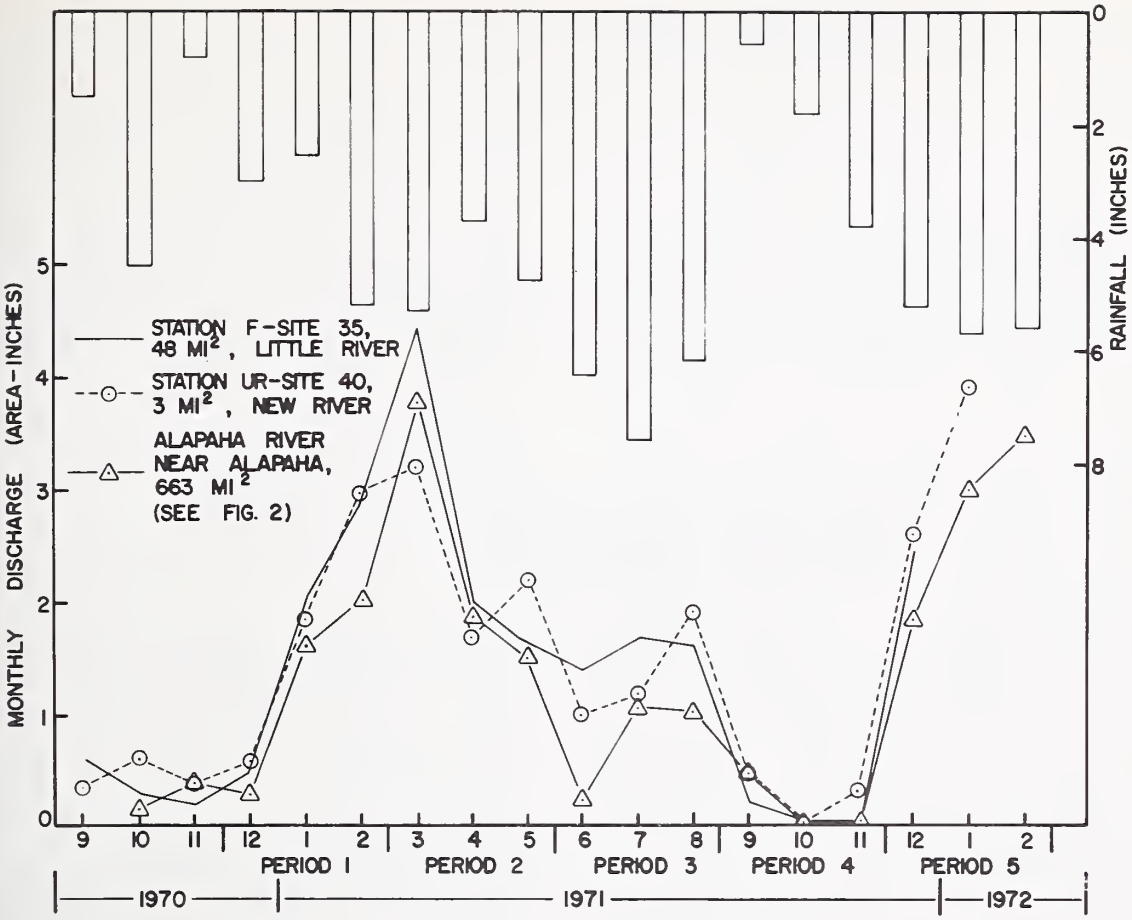


FIGURE 3.—Streamflow and precipitation (Georgia Coastal Plain, Tifton, Ga., monthly totals) at selected sites in southern Georgia.

monium molybdate). Colorimetric procedures were used to determine total phosphate. The lowest detectable concentration was 0.125 p/m.

*Chemical oxygen demand* was determined by the low-level test. Organic and oxidizable inorganic substances in an aqueous sample were oxidized by potassium dichromate solution in 50-percent (by volume) sulfuric acid solution. The excess dichromate was titrated with standard ferrous ammonium sulfate, using ferroin as an indicator.

*Total iron* (Fe) was determined by the phenanthroline colorimetric method.[5] Iron was brought into solution and reduced to the ferrous state by boiling with hydrochloric acid and hydroxylanine. The ferrous iron solution was then treated with 1,10-phenanthroline at pH 3.2–3.3. The lowest detectable level was 0.50 p/m.

[5]Ibid., pp. 156–159.

*pH* determinations were made with a digital pH meter.

## SURVEY RESULTS

### General Trends

Based on the water characteristics considered in the study, the quality of rural-agricultural streamflow was higher than that of urban streamflow in the portion of the Coastal Plain surveyed. There was a definite difference in conductivity between the rural-agricultural and rural-agricultural watershed with *definite* urban influence, as shown in figure 4. Similar trends were evident for the other characteristics inventoried, with the exception of iron. There was no appreciable difference between the quality of alluvial ground water and streamflow in rural-agricultural areas.

The mixing of the rural-agricultural streamflow with urban and suburban streamflow re-

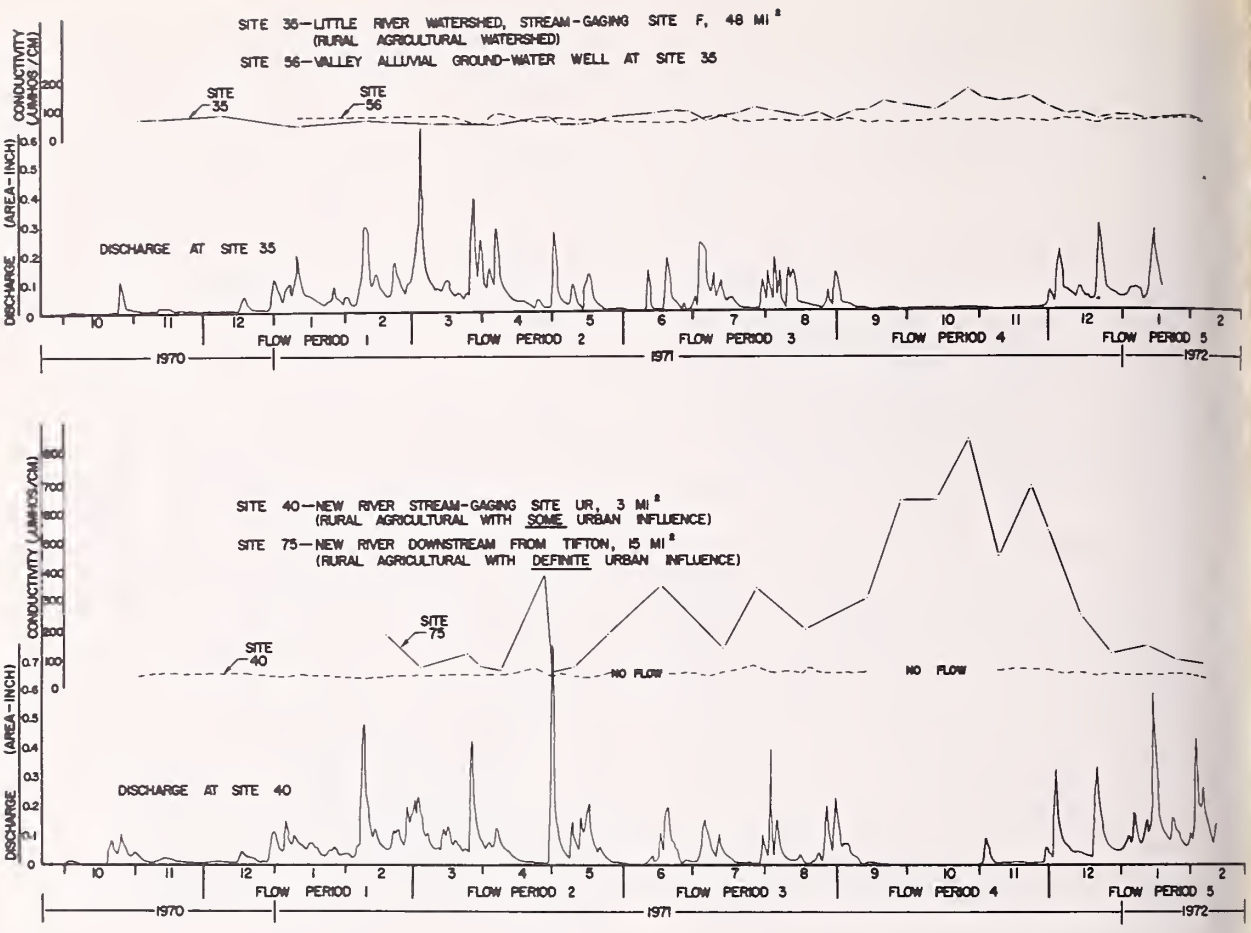


FIGURE 4.—Comparative conductivity of streamflow: Alluvial ground water versus streamflow in a rural-agricultural watershed (*top*) and urban influence on rural-agricultural streamflow (*bottom*). Conductivity also varied with seasonal discharge.

sulted in improved water quality downstream from populated areas. The distance required for dilution depends upon (1) relative urban and rural-agricultural streamflow, (2) population density and stage and type of urban development, (3) watershed size, and (4) antecedent precipitation and streamflow.

Seasonal changes in streamflow, water quality (except iron content), and streamflow quantity (figs. 3 and 4) occurred during the study period. The seasonal changes were more pronounced in the urban-suburban watersheds and the agricultural watersheds with *definite* urban-suburban influence than in the rural-agricultural watersheds. As runoff from agricultural areas decreased, water quality became poorer in streams below urban areas, but not below rural-agricultural areas.

The magnitude of the effect of population density on streamflow quality also changed with seasonal discharge. The highest concentrations of the water quality characteristics were observed in the low-flow late summer period (4), and the lowest concentrations were measured during the highest discharge periods (1, 2, 3, and 5) of the winter and early spring.

## POPULATION DENSITY AND WATER QUALITY

The concentrations of $Cl^-$, N, and P in streamflow increased as population density increased and varied with the season. Iron content seemed to be related to the stratigraphy, soils, and cultural practices in the watershed rather than to population density. Chemical oxygen demand was related to population density only during low-flow periods; during periods of in-

termediate-to-high flow, sufficient streamflow was available to mask the effect of population.

Population densities of less than 400 per square mile had no effect on water. At higher densities, however, seasonal changes in discharge changed the minimum density that affected water quality: The lower the discharge, the smaller the number of people per unit area that could be supported without detrimentally affecting water quality.

The effect of population density and seasonal runoff on water quality is shown in figures 5–9. Each point on the graphs is the average of all samples collected at a site during the period given. Several sites were abandoned in midsummer 1971 (appendix). However, the relation of population density to water quality is still discernible.

*Conductivity.*—During the high-runoff periods from December 1970 through May 1971, conductivity (fig. 5) was less than 100 $\mu$mhos/cm for populations less than 400/mi$^2$. Above this population density, conductivity gradually increased to a maximum of 350 $\mu$mhos/cm. From June through August 1971, an intermediate-runoff period, conductivity reached 450 $\mu$mhos/cm. Conductivity increased during the fall, September–November 1971, the period of lowest runoff. Conductivity was, in general, about 100 $\mu$mhos/cm for population densities as low as 100/mi$^2$, reaching a high of approximately 700 $\mu$mhos/cm. However, this was followed by the high winter runoff period (December 1971–February 1972), and the density that the streamflow could support before the conductivity increased above 100 $\mu$mhos/cm rose again to approximately 400/mi$^2$.

*Chlorides.*—The chloride concentration pattern (fig. 6) was the same as that for conductivity. The maximum average chloride concentration observed during the wet season (March–May) was 40 parts per million (p/m) and increased to 50 p/m during the summer (June–August). A maximum of 90 p/m was reached during the fall (September–November), and then the concentration dropped to 40 p/m during December 1971 through February 1972. There was a minimum population that did not appreciably affect the concentration of chlorides. This population density varied seasonally. During the dry fall, populations as low as 200/mi$^2$ affected chloride concentration. During the wet winter season, populations as high as 400 to 600/mi$^2$ had little effect.

*Total nitrogen.*—Nitrogen determinations were started in March 1971. As in the case of conductivity and chlorides, seasonal runoff and population density affected concentration (fig. 7). The highest quarterly average, 7 p/m, occurred during the low-discharge fall season (September–November). The highest average value for the rest of the study period was 3 p/m. Values were below 1.5 p/m during all seasons in rural-agricultural areas.

*Total phophorus.*—Average total phosphorus concentrations (fig. 8) from areas with population less than 400/mi$^2$ were almost always below the detection level of 0.125 p/m, even in the dry season. The maximum average concentration for sites with population greater than 1,000/mi$^2$ was approximately 5.0 p/m during the low-flow season (September–November). Concentrations were below 1.1 p/m for populations of 1,000/mi$^2$ for all seasons except the fall.

*Chemical oxygen demand.* — Variation in chemical oxygen demand (fig. 9) with population density was not pronounced. The only detectable difference was measured in the low-runoff season of late summer and fall (September–November). Average quarterly values ranged from a minimum of approximately 10 p/m to a maximum of 67 p/m. Values, in general, were only slightly higher in areas with high population densities.

## Seasonal Effects on Water Quality

There was pronounced seasonal change in the water quality of the urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban influence, but not in the water quality of the rural-agricultural watersheds and rural-agricultural watersheds with *some* urban-suburban influence. The seasonal changes in conductivity, chlorides, total nitrogen, total phosphorus, chemical oxygen demand, and total iron are shown in figures 10–15.

The curves are plotted from individual sample concentrations at specific times. Chemical oxygen demand and iron were the only two characteristics that had a different pattern.

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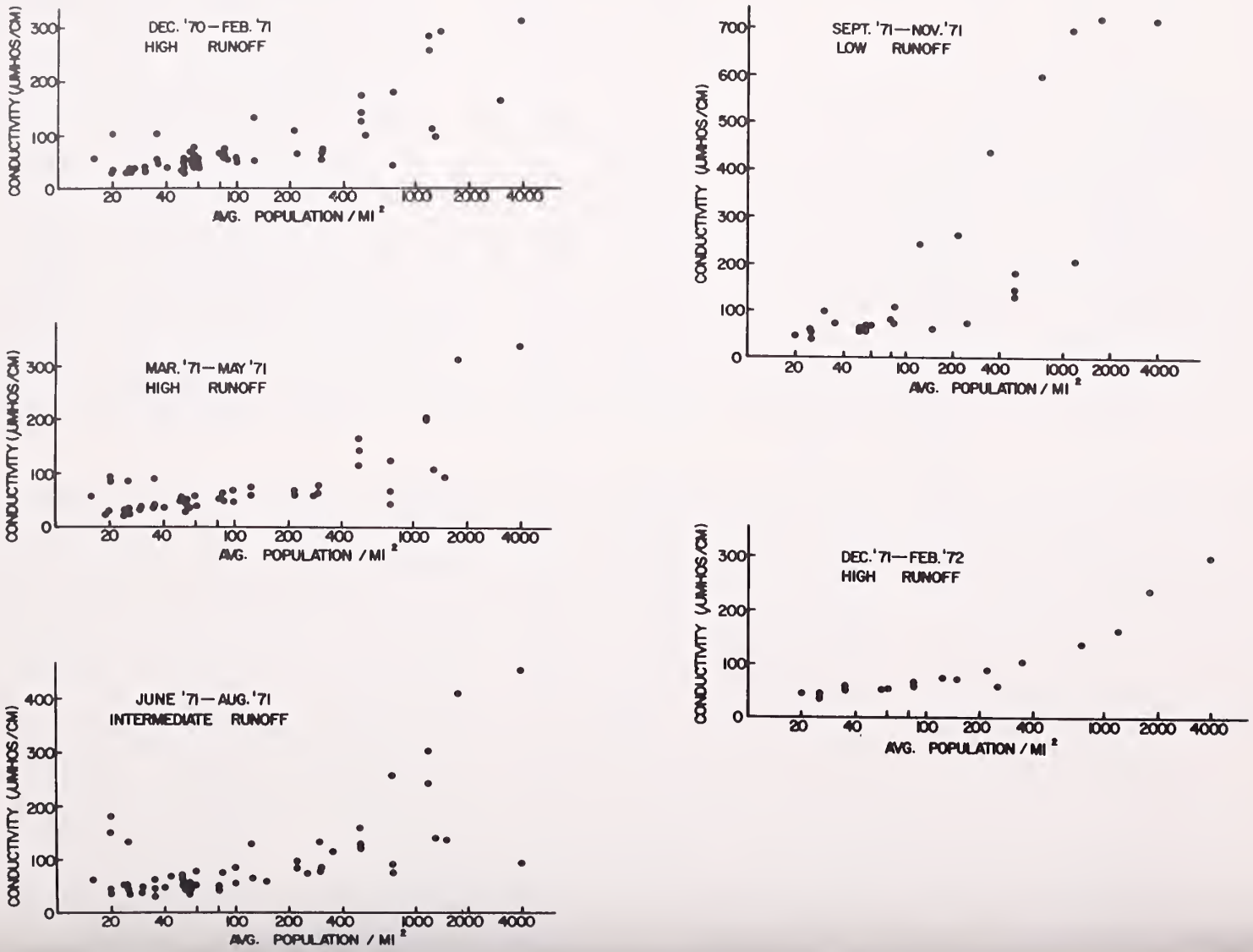



FIGURE 5.—Conductivity as affected by average population density and seasonal runoff.

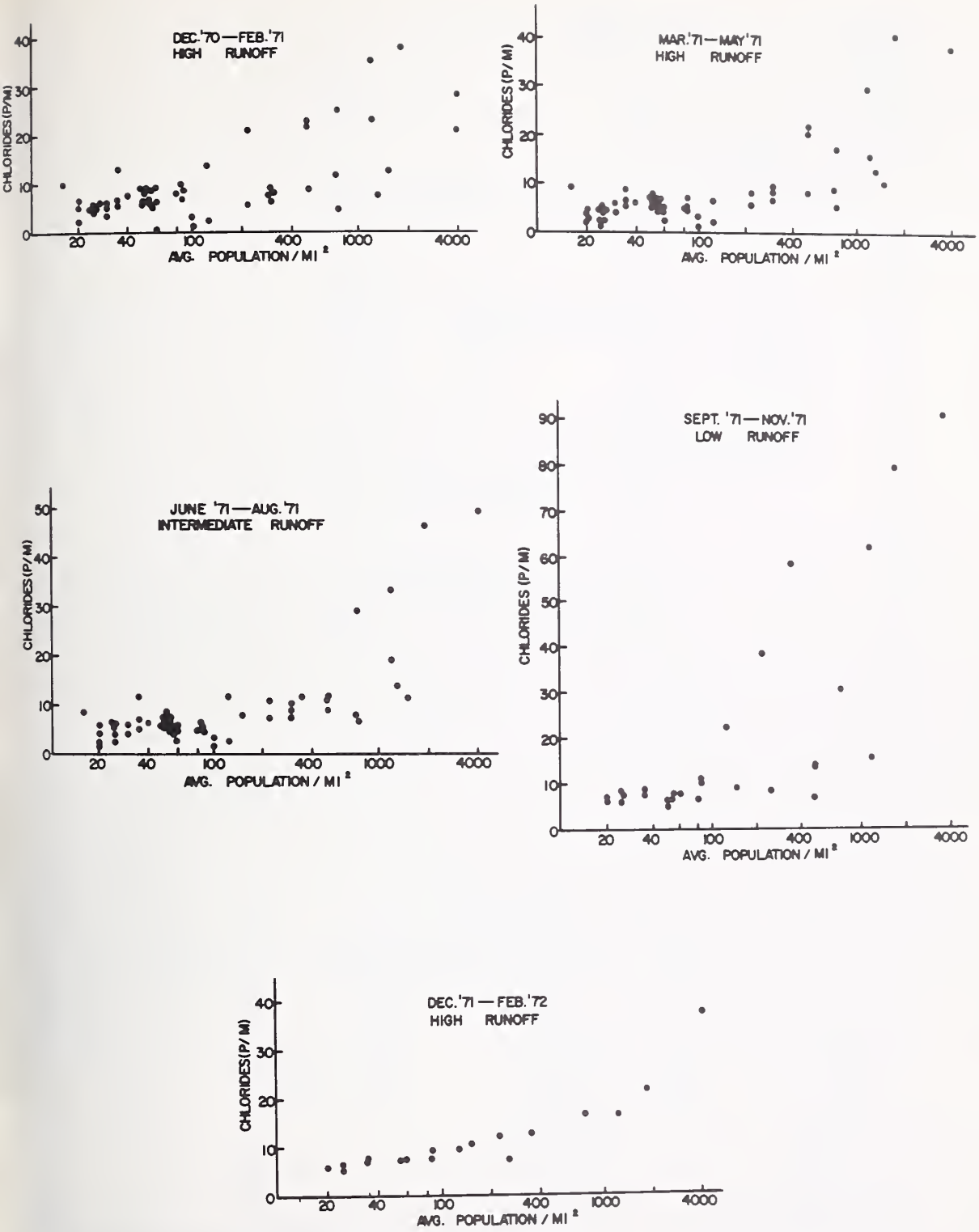



FIGURE 6.—Chloride concentration as affected by average population density and seasonal runoff.

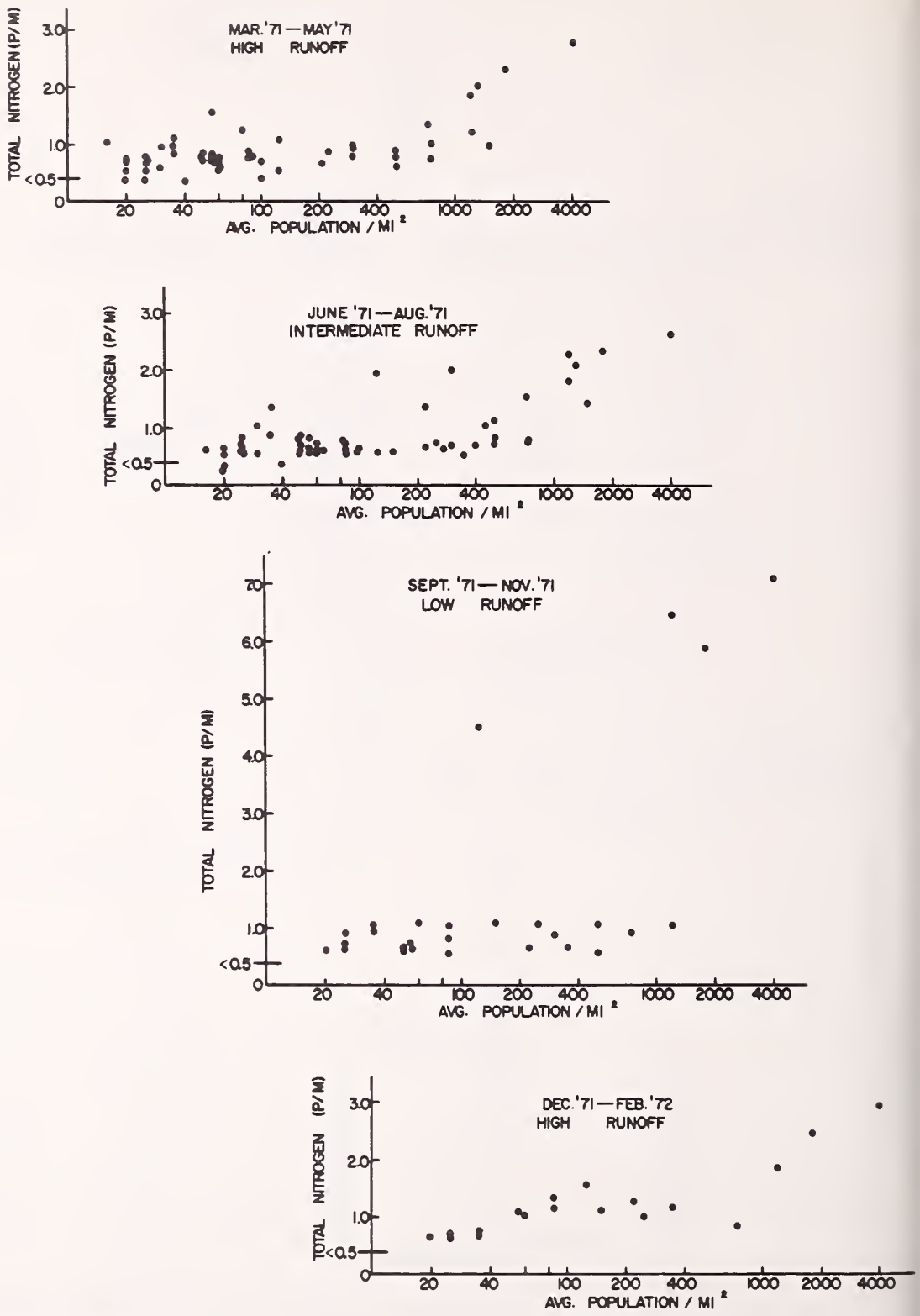



FIGURE 7.—Total nitrogen concentration as affected by average population density and seasonal runoff

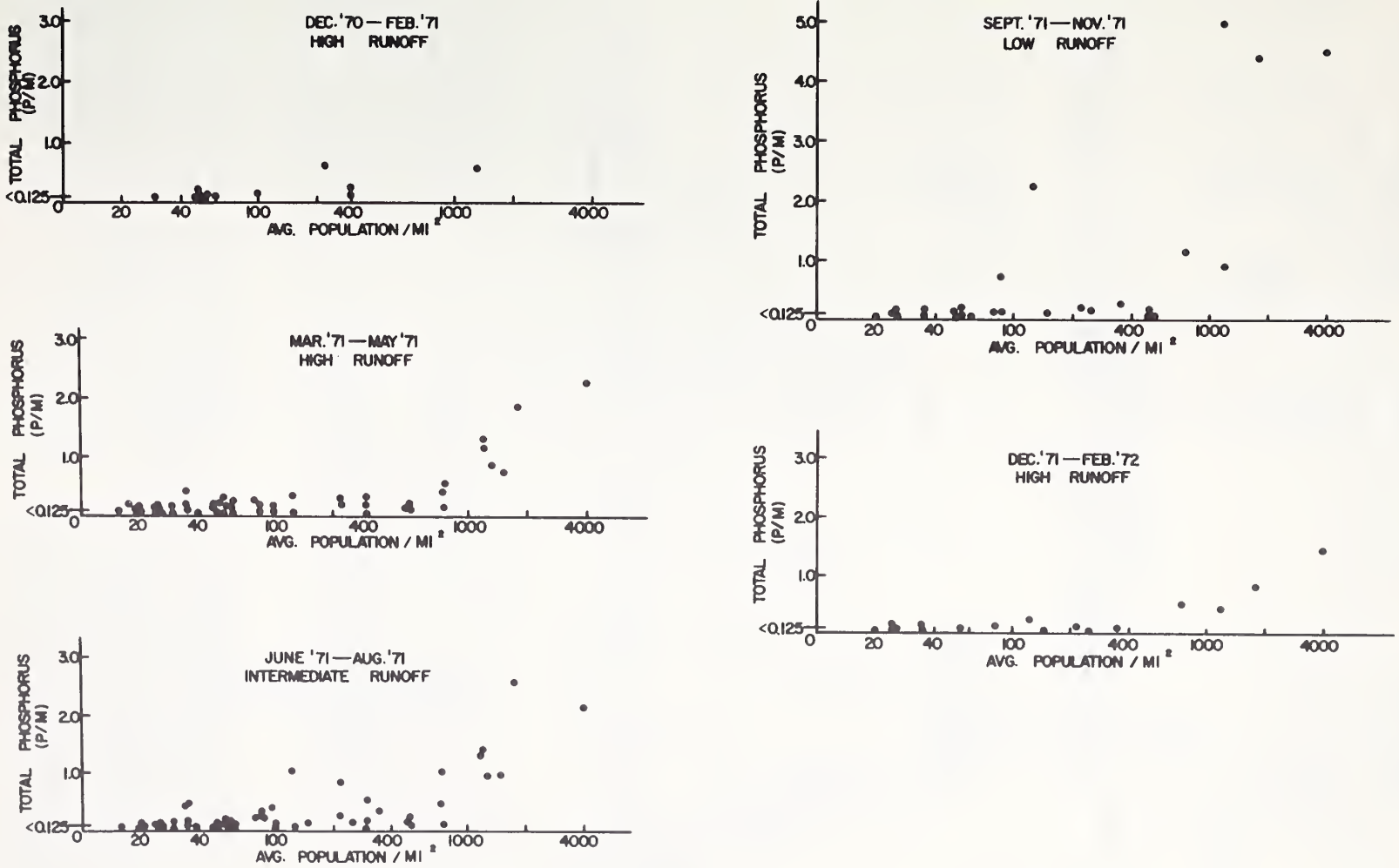



FIGURE 8.—Total phosphorus concentration as affected by average population density and seasonal runoff.

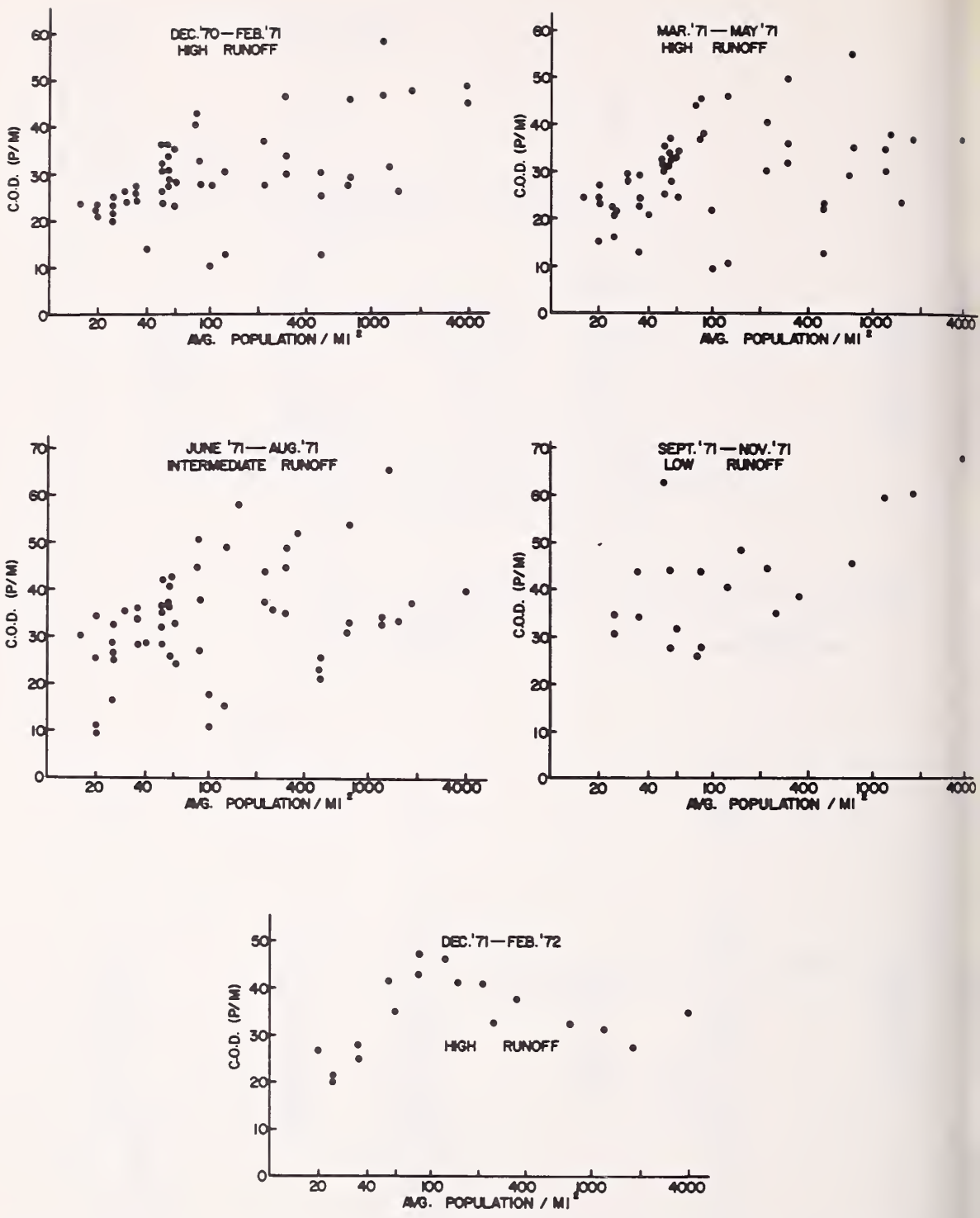



FIGURE 9.—Chemical oxygen demand (C.O.D.) as affected by average population density and seasonal runoff

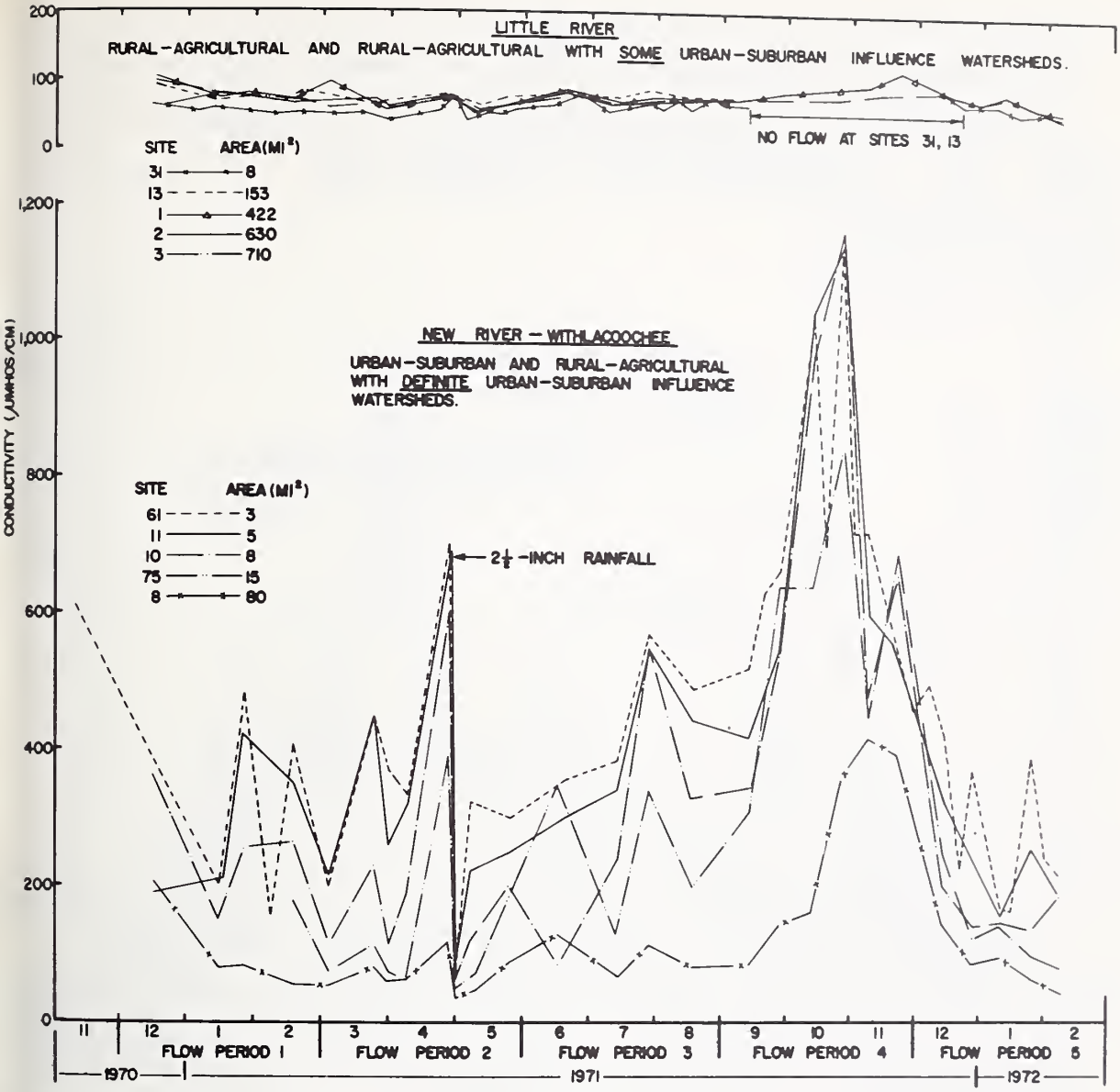



FIGURE 10.—Conductivity of samples from urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban influence compared to adjoining rural-agricultural watersheds and rural-agricultural watersheds with *some* urban-suburban influence. Seasonal conductivity changes and downstream dilution are reflected in the curves of the urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban runoff.

Chemical oxygen demand was about equal for both kinds of watersheds (fig. 14) except during the low runoff period (September–November 1971) when the New River-Withlacoochee watershed showed some seasonal change. Total iron concentrations did not change seasonally or between the two major watershed groups (fig. 15).

The water quality characteristics except chemical oxygen demand and iron responded similarly to rainfall and runoff. This is shown in late April of 1971 when the concentrations were rising. A 2½-inch rain occurred, and an immediate drop in concentration occurred. Hence, relatively uniform monthly distribution of rainfall could conceivably beneficially affect

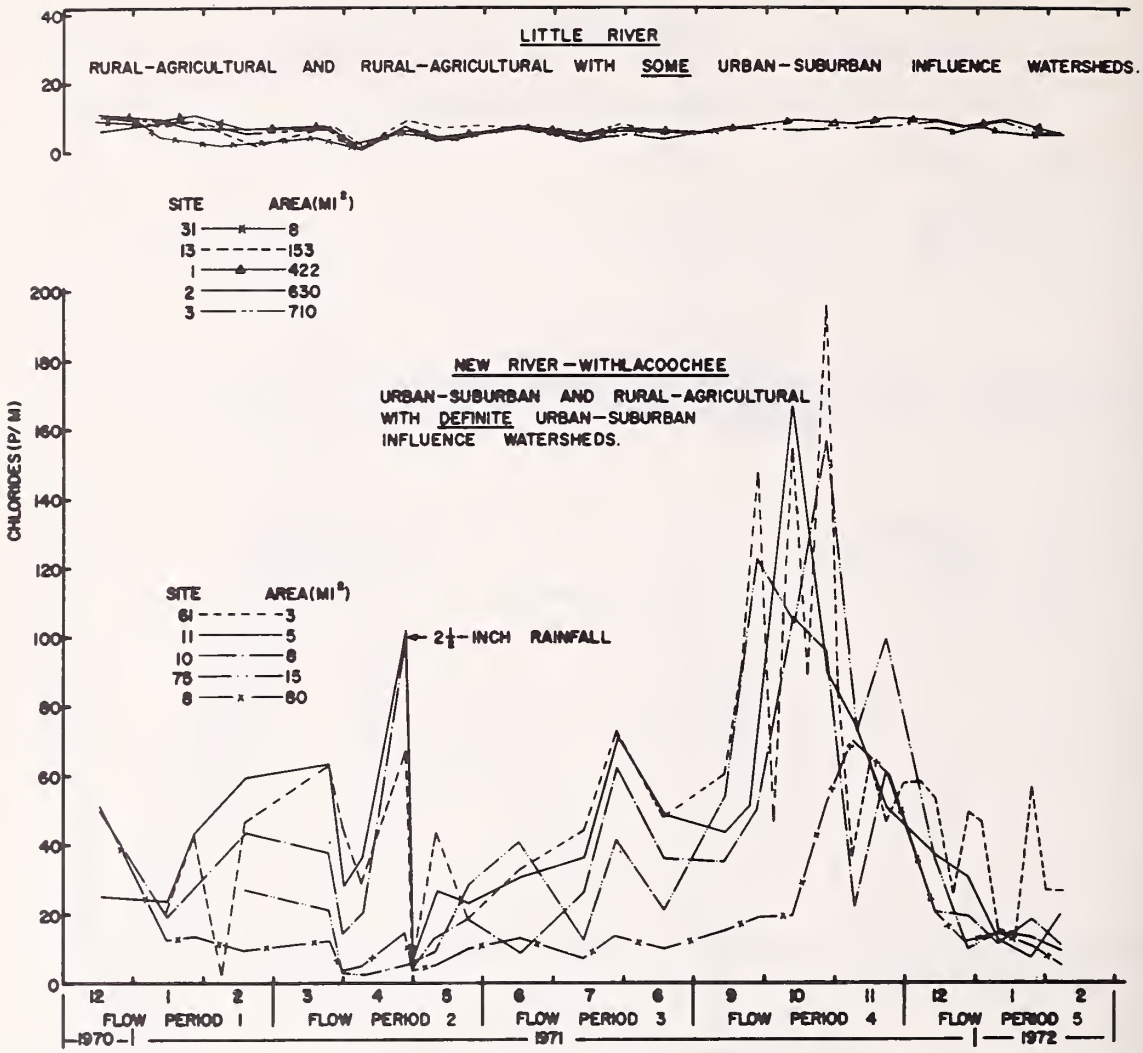



FIGURE 11.—Chloride values from urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban influence compared to adjoining rural-agricultural watersheds and rural-agricultural watersheds with *some* urban-suburban influence. The effects of seasonal $Cl^-$ changes and downstream dilution are reflected in the curves of the urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban runoff.

water quality. The uniform distribution of rainfall, except for the fall, provided a relatively constant streamflow rate from the agricultural areas for the dilution of urban-suburban streamflow (fig. 3). This streamflow supported only certain population densities with presently used methods of waste disposal in this area without deleterious effects on water quality. When populations exceeded this density, water quality was not controlled by dilution with rural-agricultural streamflow. Therefore, it would be desirable to prolong streamflow (reduce peak discharge) from rural-agricultural areas into the dry season by the use of water management practices to provide more dilution of urban streamflow.

## Downstream Dilution of Urban Streamflow by Rural-Agricultural Runoff

Sites were selected on the New River-Withlacoochee watershed (fig. 2) to inventory downstream dilution of urban streamflow. These sites extended from upstream of Tifton on New River to downstream at site 7, where New

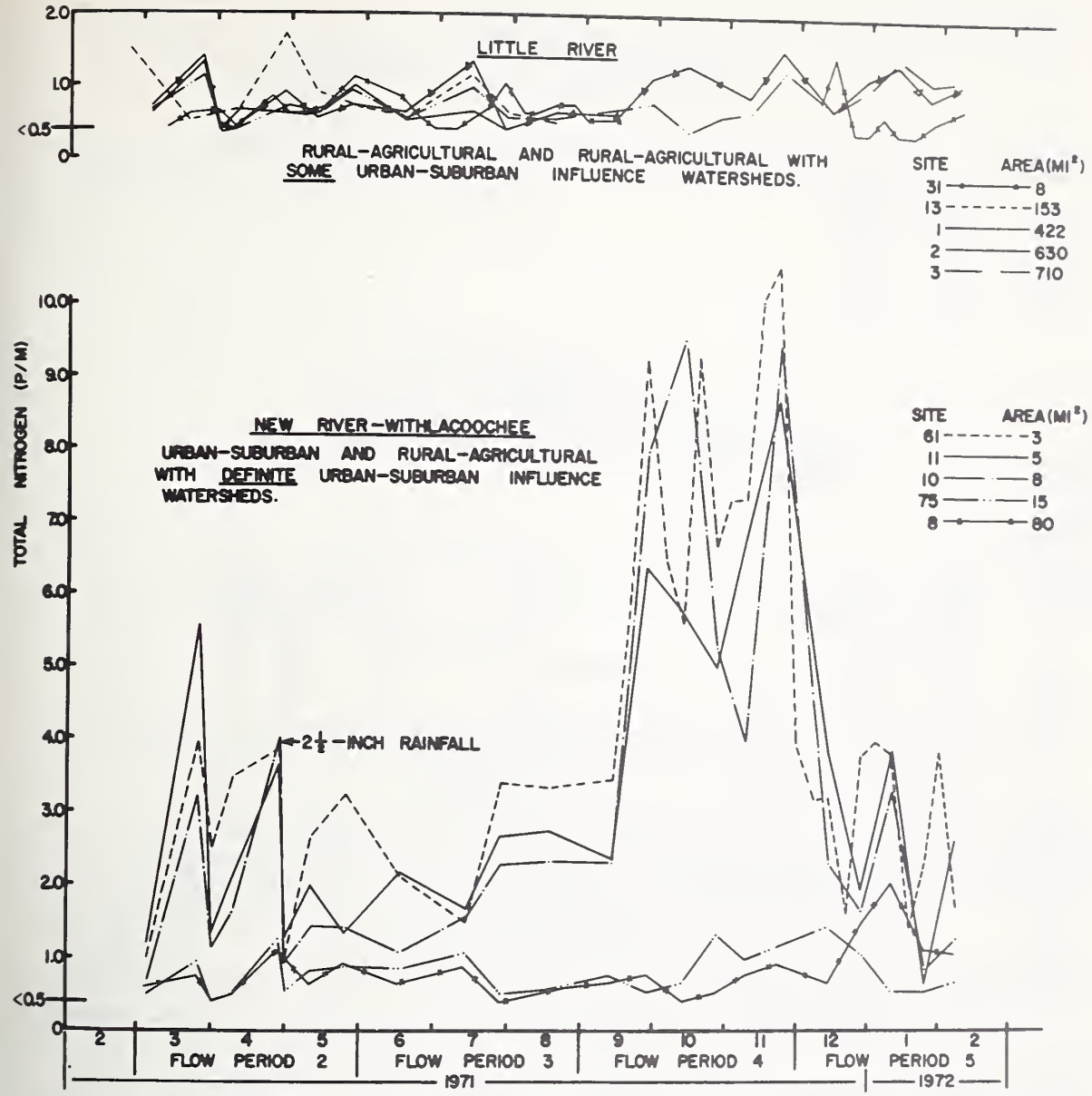



FIGURE 12.—Total nitrogen values from urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban influence compared to adjoining rural-agricultural watersheds and rural-agricultural watersheds with *some* urban-suburban influence. The effects of seasonal nitrogen concentration changes and downstream dilution are reflected in the curves of the urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban runoff.

River runs into the Withlacoochee River. Site 4 was the last site on the Withlacoochee before its confluence with Little River at Valdosta. Site 5 reflects the mixing of streamflow from the rural-agricultural Little River watershed with that from the Withlacoochee watershed, which contains the cities of Tifton, Valdosta, Nashville, Alapaha, Adel, Hahira, and Lenox. Figures 16 to 20 all show downstream dilution of the water quality characteristics. The values shown are averages of all samples collected during each period at each site. Sites were selected going from the headwater areas downstream. The distance downstream that the concentrations were affected by urban-suburban populations varied with the water quality characteristic, season, water treatment practices, and population densities.

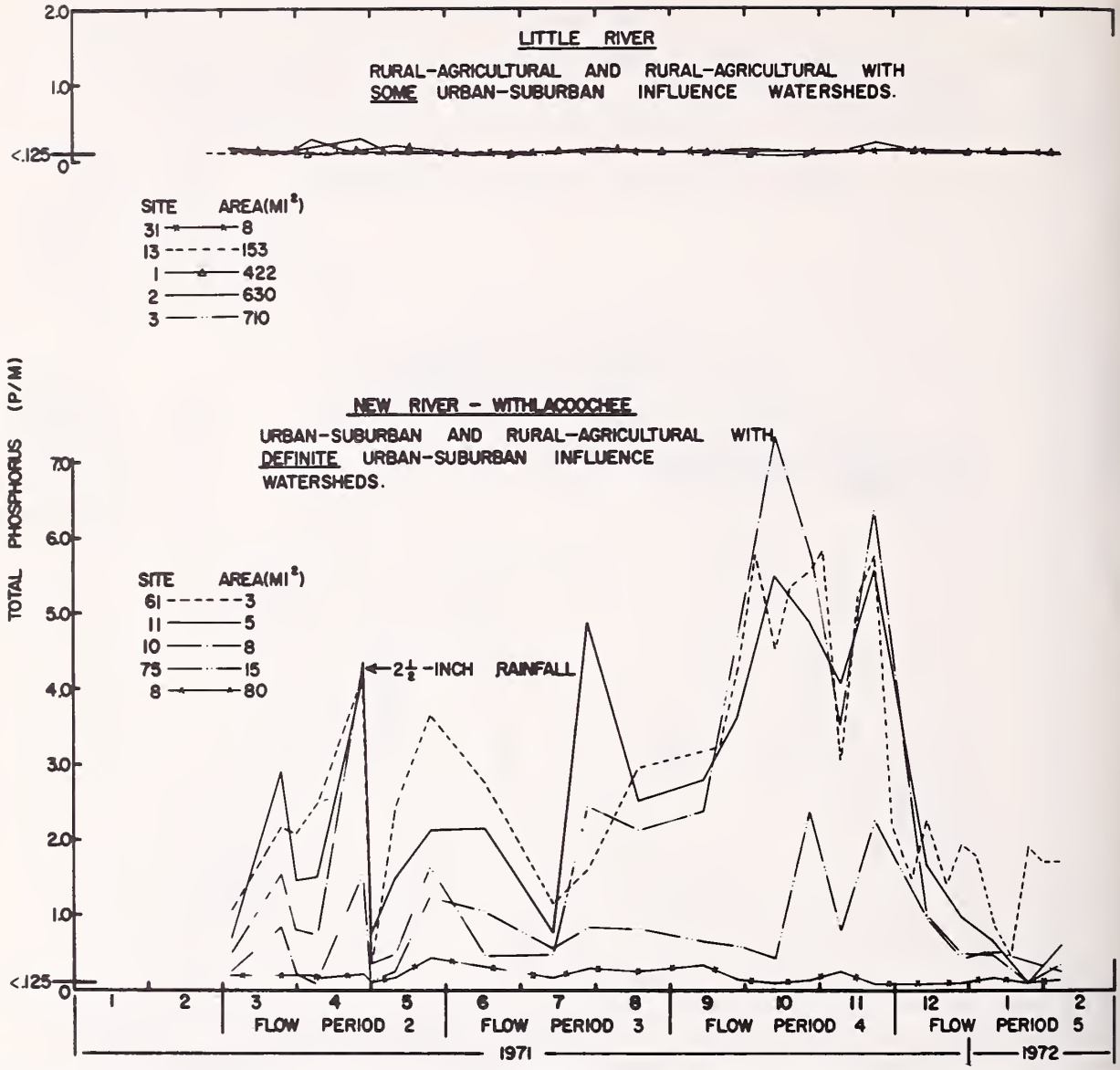



FIGURE 13.—Total phosphorus values from urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban influence compared to adjoining rural-agricultural watersheds and rural-agricultural watersheds with *some* urban-suburban influence. The effects of seasonal phosphorus changes and downstream dilution are reflected in the curves of the urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban runoff.

*Conductivity.*—At site 61, for example, conductivity ranged from approximately 300 μmhos/cm in wet season (December–May) to 450 μmhos/cm in the summer (June–August) to a high of 750 μmhos/cm in the dry season (September–November). Other sites also showed the seasonal effect. Site 7 did not show an increase even during the dry season. Hence, it can be inferred that the watershed above this site produced enough good-quality streamflow to support its population density. The watershed area necessary to support the population during September through November can be noted when figure 5 is compared to figure 16. Concentrations at site 10 during this period (fig. 16) were the same as those at sites 61 and 11, and only slightly greater than those at 75. This indicates that sufficient runoff was

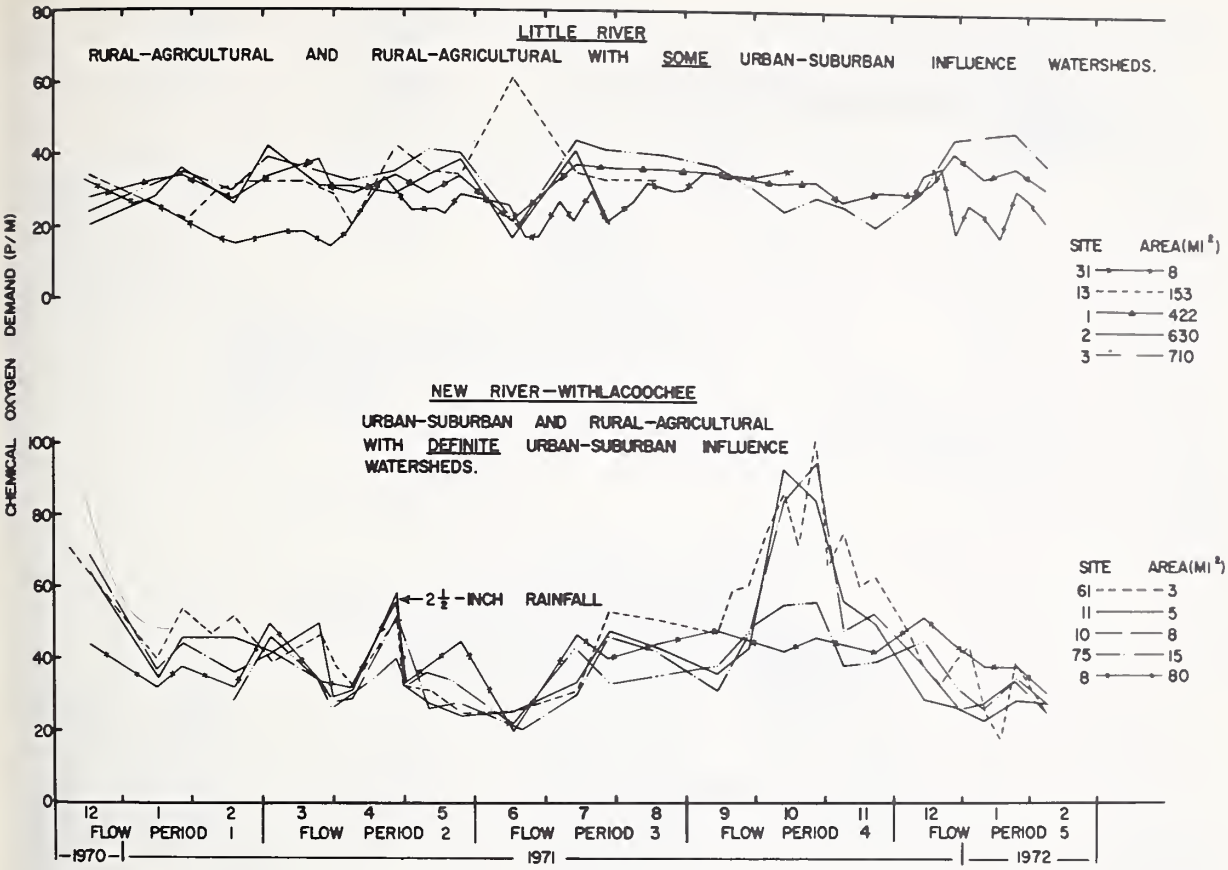



FIGURE 14.—Chemical oxygen demand values from urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban influence compared to adjoining rural-agricultural watersheds and rural-agricultural watersheds with *some* urban-suburban influence. The effects of seasonal chemical oxygen demand changes and downstream dilution are reflected in the curves of the urban-suburban watersheds and rural-agricultural watershed with *definite* urban-suburban runoff.

not available to decrease the conductivity even as far downstream as site 75. During the other seasons, approximately one-half the dilution was accomplished by the time the urban discharge reached site 10. It can be seen that a watershed containing both rural-agricultural and suburban-urban areas can produce streamflow with a quality that does not deteriorate during low-flow periods if the population density remains below a certain number.

*Chlorides.*—Chloride concentrations (fig. 17) exhibited the same downstream dilution trend as conductivity. The concentration rose from approximately 40 p/m during December–May to approximately 49 p/m during June–August to a high of approximately 100 p/m during September–November. The concentration at sites 7 and 5 varied from 5 to 10 p/m throughout the study period, showing no additional dilution.

*Total nitrogen.*—The nitrogen survey, started in March 1971, resulted in the same downstream dilution trend (fig. 18) as shown by conductivity and chlorides. However, nitrogen dilution below Tifton seemed to occur above site 75. Conductivity and chloride dilution was still occurring above site 7. Maximum total nitrogen concentrations were 2.5 p/m during March–August and 7.0 p/m during September–November. Concentrations at site 4 showed a definite effect of additional urbanization, whereas this effect was not as pronounced in the case of conductivity and chlorides. During the dry period the pronounced effect of the mixing with Little River runoff can be noted.

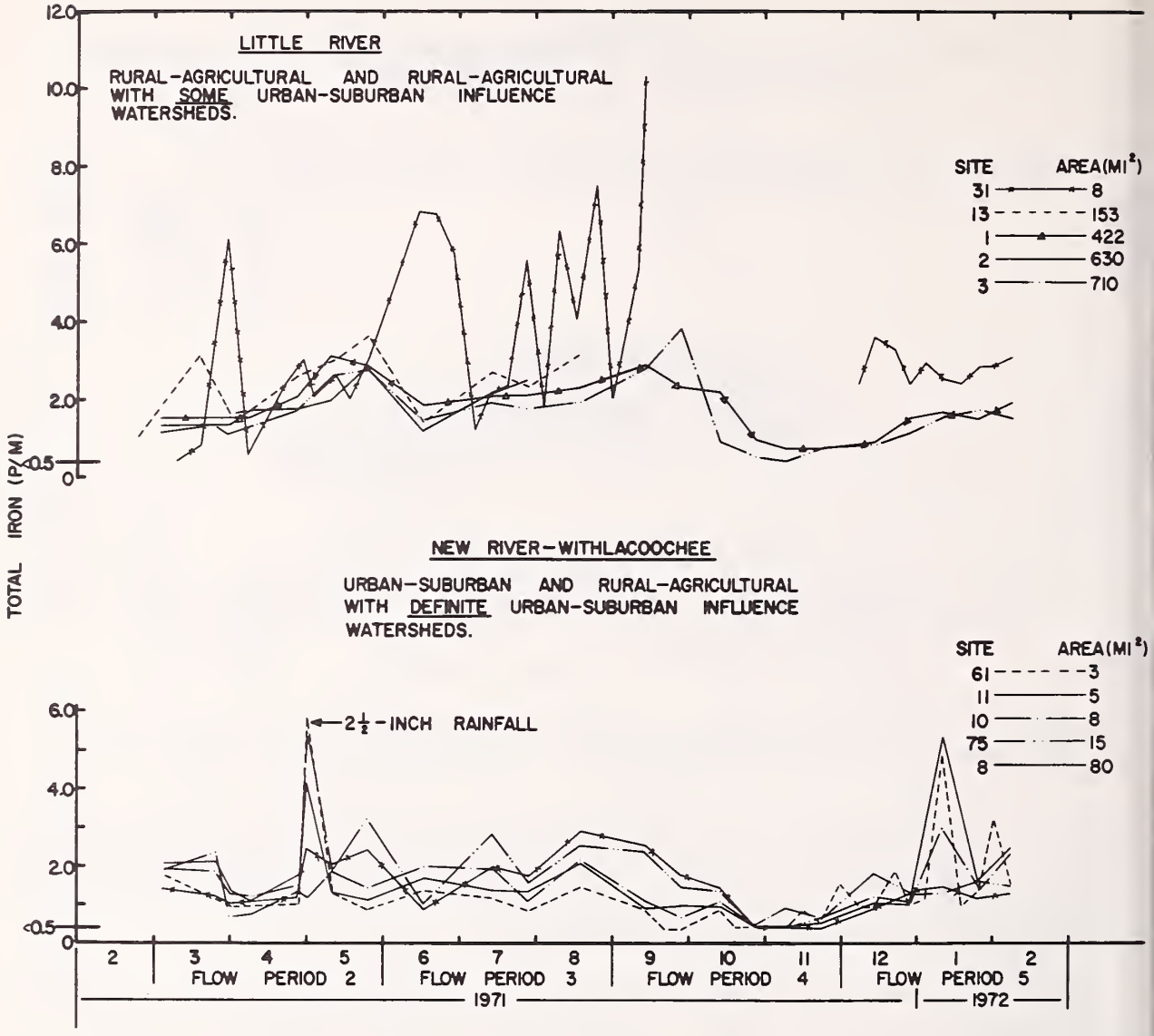



FIGURE 15.—Total iron values from urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban influence compared to adjoining rural-agricultural watersheds and rural-agricultural watersheds with *some* urban-suburban influence. The effects of seasonal iron concentration changes and downstream dilution are reflected in the curves of the urban-suburban watersheds and rural-agricultural watersheds with *definite* urban-suburban runoff.

*Total phosphorus.* — Phosphorus concentrations (fig. 19) varied seasonally and exhibited downstream dilution trends about the same as nitrogen. The only difference between the two characteristics was the downstream distance required for dilution. Maximum phosphorus concentrations ranged from approximately 2.0 p/m during March–August to a maximum of 4.5 p/m during September–November. Again, as in the case of nitrogen, the pronounced effect of the mixing with Little River runoff at site 5 can be noted.

*Chemical oxygen demand.* — There was no downstream dilution of chemical oxygen demand except during the fall, September–November (fig. 20). Values ranged from a maxi-

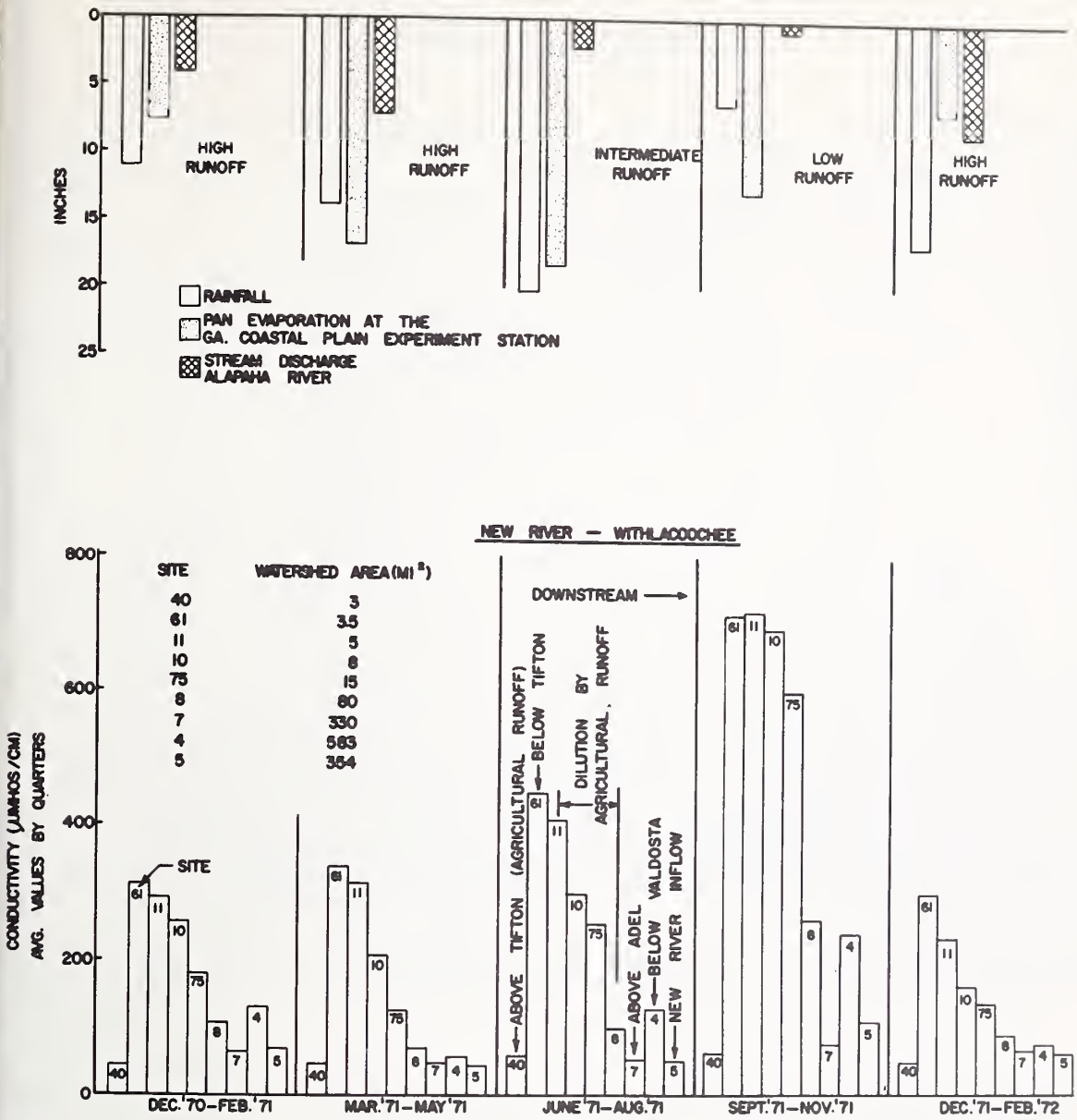



FIGURE 16.—Downstream dilution of conductivity below an urban-suburban area. Seasonal variation in conductivity is also reflected by variation in average quarterly values.

mum of 48 p/m during December–August to a high of 68 p/m during September–November and were as low as 25 p/m during high runoff periods.

*Total iron.*—There was no downstream dilution of total iron (fig. 21). Concentrations ranged from 0.5 to 5.2 p/m, but were generally constant at approximately 1.0 to 2.0 p/m. There was no significant difference in iron concentrations between urban or rural-agricultural watersheds.

## Pond Sites

Four ponds were surveyed: Walker Pond, the two Hardy Ponds (one draining pasture, the other cultivated cropland), and Lake Mary.

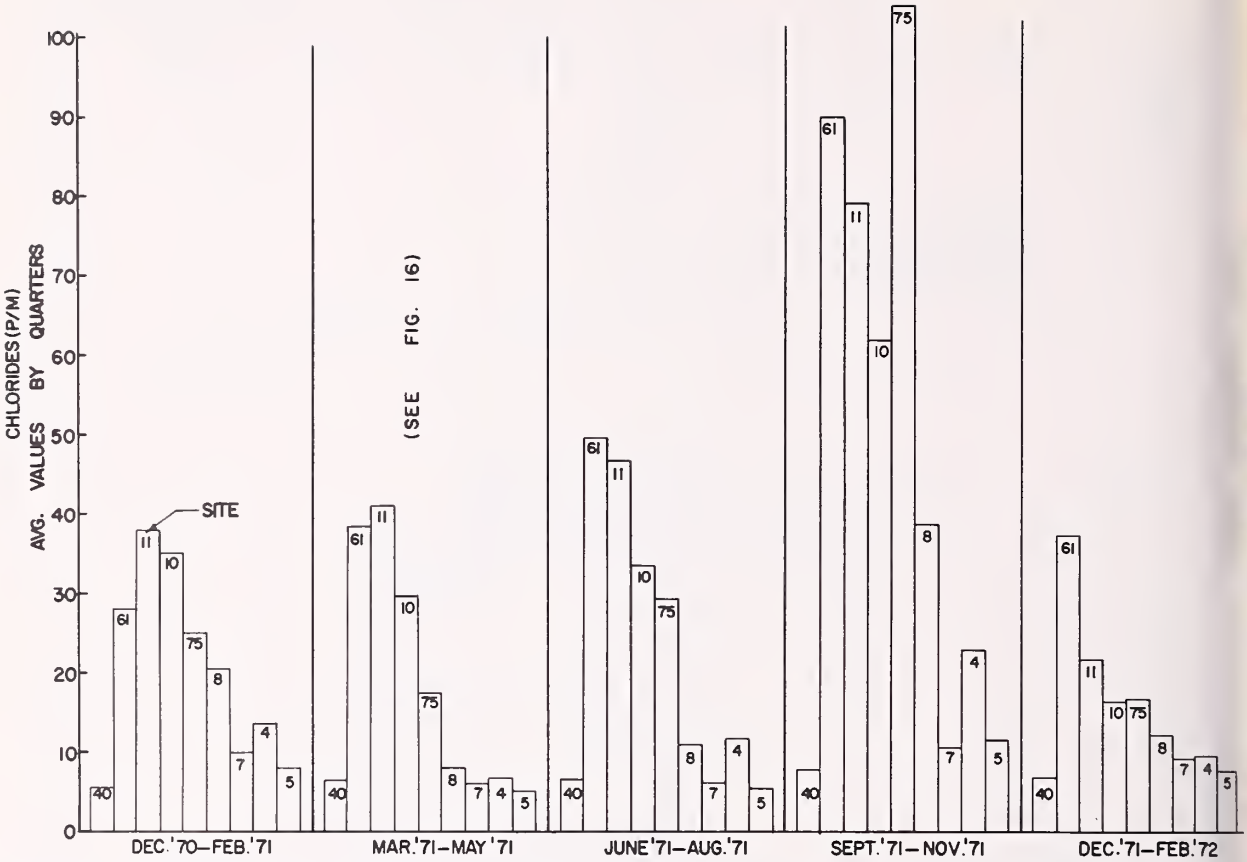
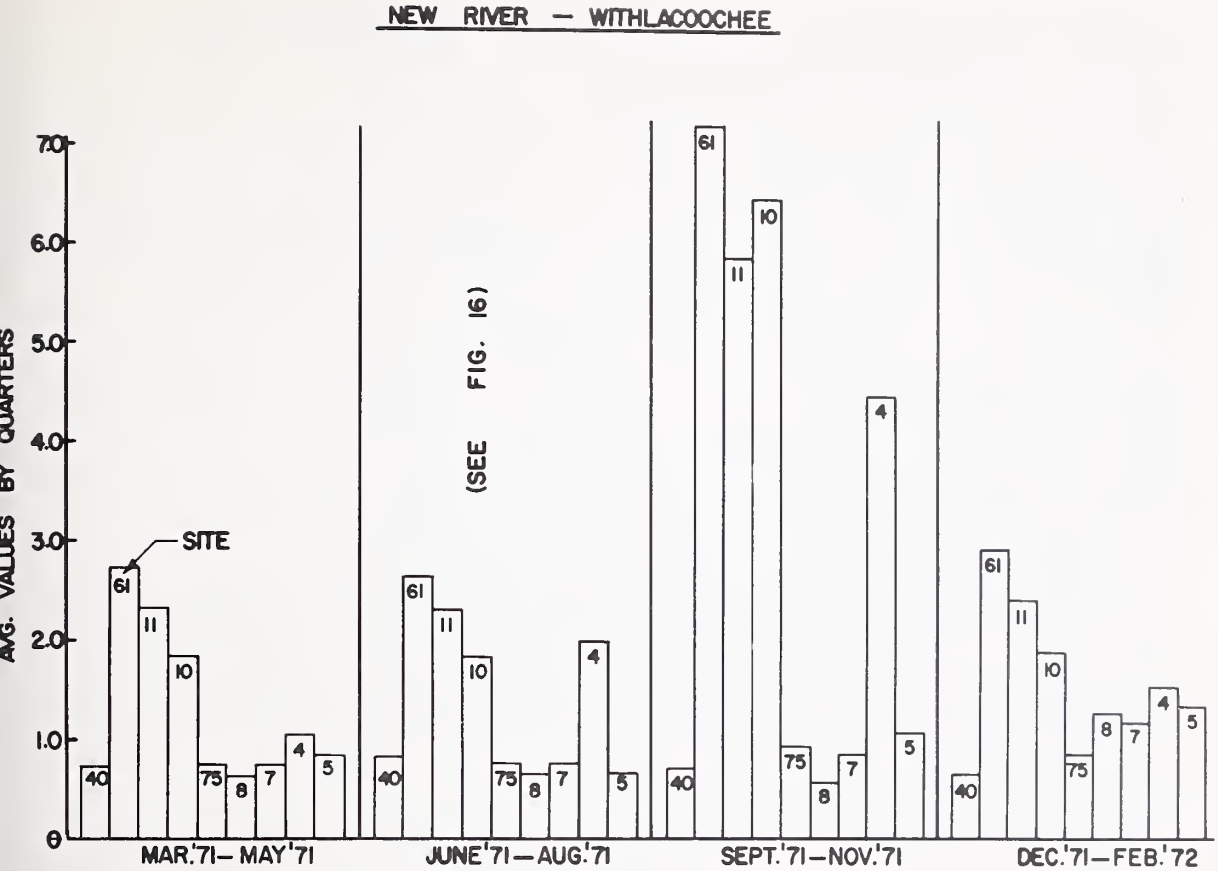



FIGURE 17.—Downstream dilution of chlorides below an urban-suburban area. Seasonal variation is also reflected by variation in average quarterly values. Rainfall, streamflow, and pan evaporation are shown on figure 16.

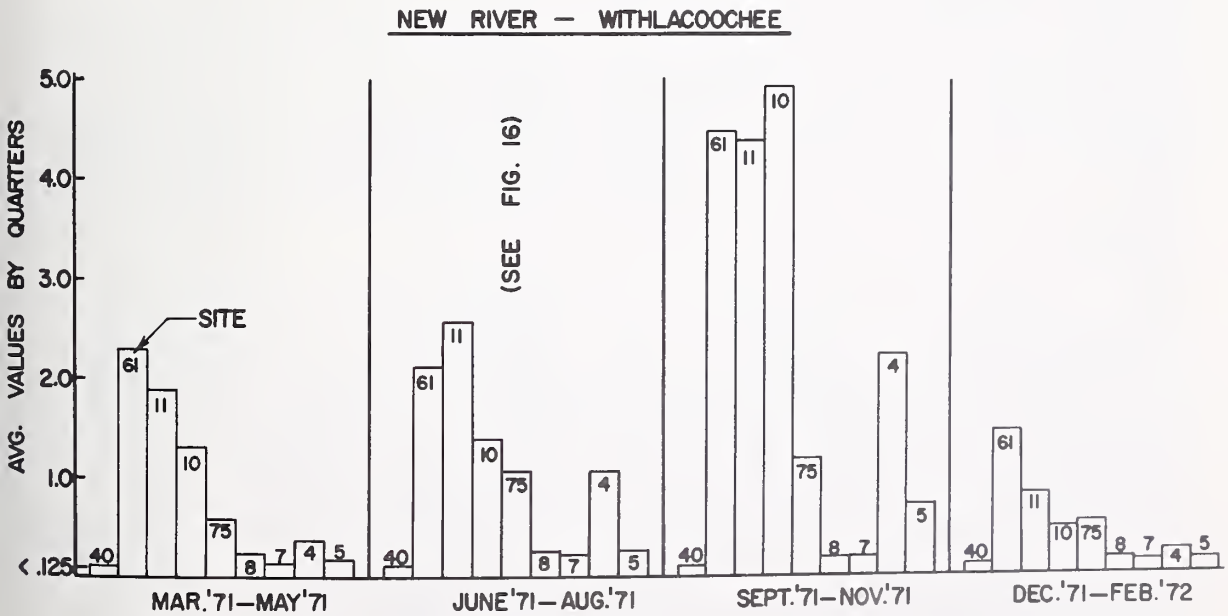
The watershed above Walker Pond and the Hardy Ponds is entirely agricultural. Walker Pond watershed is about 67 percent cultivated cropland, 11 percent pasture, and 22 percent woodland. Drainage into Lake Mary is from a mixed agricultural and urban-suburban area. Septic tanks provide the urban sewage disposal upstream from Lake Mary.

Figure 22 shows the average monthly concentrations of the water quality characteristics of Lake Mary and Walker Pond. The total nitrogen concentration of Walker Pond was equal to or higher than that of Lake Mary, except during February 1972. The total phosphorus concentrations for both watersheds were below the detection level. Conductivity and chloride concentrations were higher in Lake Mary than in Walker Pond with the exception of conductivity in June 1971.

The two Hardy Ponds are in an intensively managed and fertilized agricultural area. All runoff flows into the ponds. Cattle grazed intermittently on the pasture watershed with an approximate stocking rate of 2 animals/acre throughout the study period. The cropped watershed was used for production of corn, peanuts, and sweetpotatoes. Total nitrogen was higher in the pasture watershed runoff than in the cropped watershed runoff in all months except February 1972 (fig. 23). Concentrations for the pasture pond ranged from approximately 1 to 3 p/m, with May, June, and November having the highest. Total phosphorus was approximately the same in both ponds ex-




IGURE 18.—Downstream dilution of total nitrogen below an urban-suburban area. Seasonal variation is also reflected by variation in average quarterly values. Rainfall, streamflow, and pan evaporation are shown on figure 16.




IGURE 19.—Downstream dilution of total phosphorus below an urban-suburban area. Seasonal variation is also reflected by variation in average quarterly values. Rainfall, streamflow, and pan evaporation are shown on figure 16.

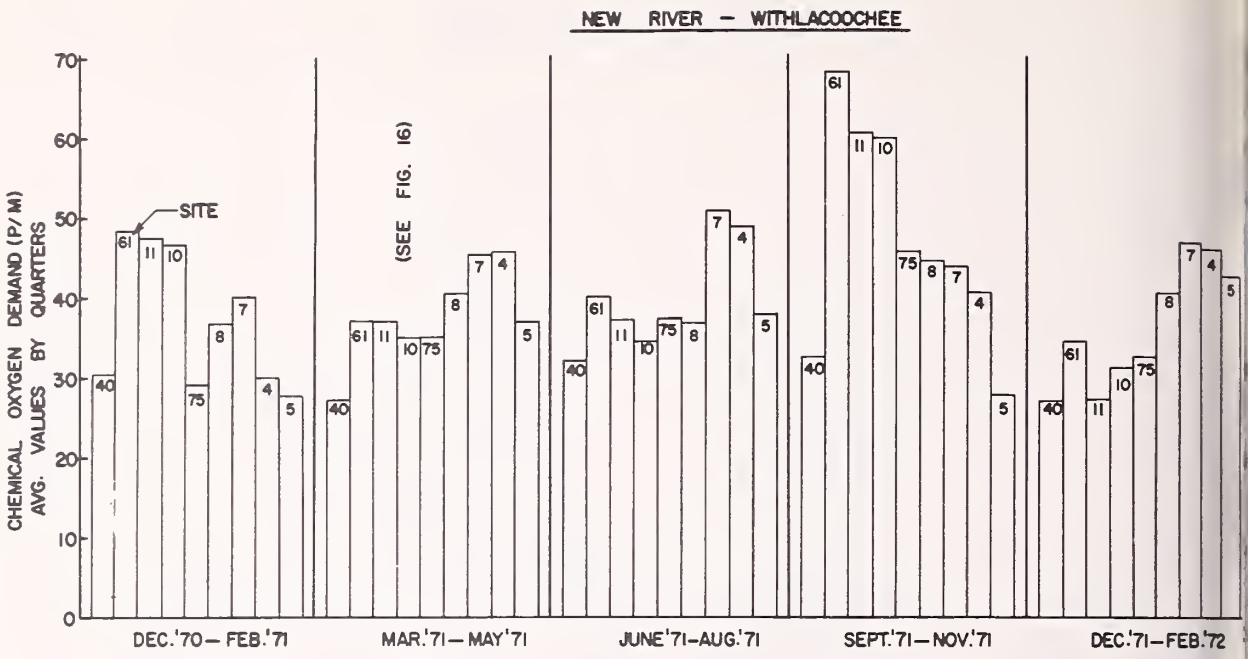



FIGURE 20.—Downstream dilution of chemical oxygen demand below an urban-suburban area. Seasonal variation is also reflected by variation in average quarterly values. Rainfall, streamflow, and pan evaporation are shown on figure 16.

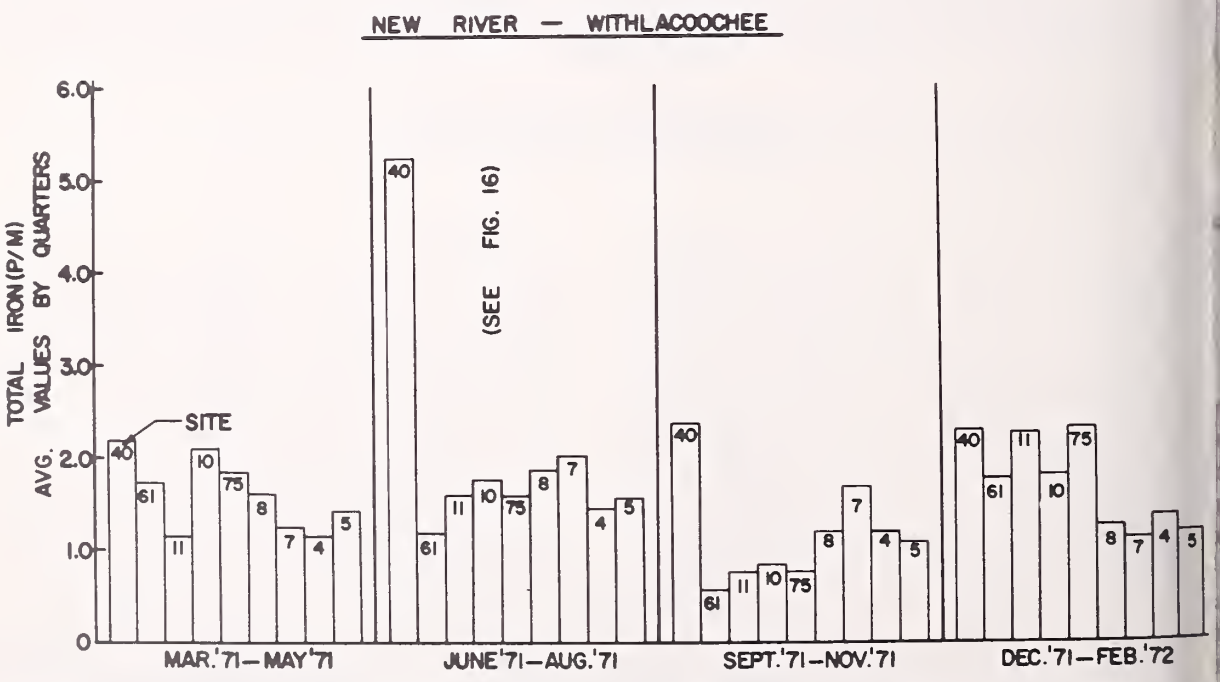



FIGURE 21.—Downstream dilution of total iron below an urban-suburban area. Seasonal variation is also reflected by variation in average quarterly values. Rainfall, streamflow, and pan evaporation are shown on figure 16.

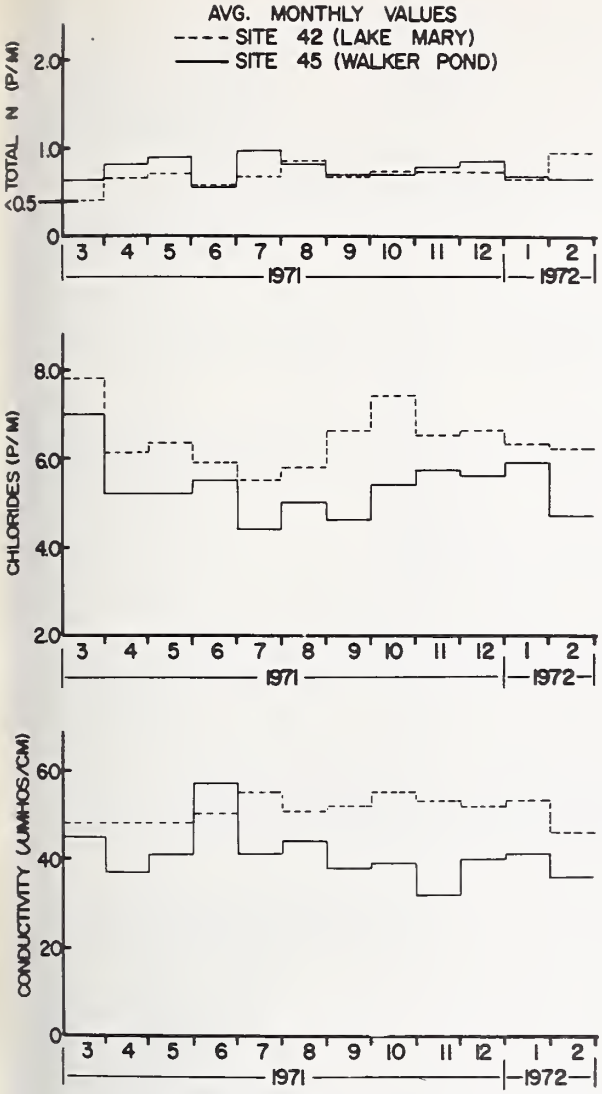



FIGURE 22.—Water quality characteristics of urban-agricultural (Lake Mary) and agricultural (Walker Pond) watersheds. Total phosphorus concentrations were below the detection level (less than 0.125 p/m).

cept for May, when the cropped watershed concentrations were higher. The pasture pond had the highest phosphorus concentration during May and June. Total phosphorus values (both ponds) ranged from less than 0.125 p/m in April to 1.3 p/m in May. All concentrations were below 0.5 p/m except for 3 months. Chloride and conductivity had the same general trend, but they were always higher in the cultivated watershed than in the pasture watershed. Chloride values (both ponds) ranged from 5.8 to 13 p/m, and conductivity ranged from 42 to 160 $\mu$mhos/cm. When looking at the water quality from the intensively treated agricultural area, it must be kept in mind that samples were taken immediately adjacent to the source area. For example, concentrations were considerably lower in Walker Pond than in the Hardy Ponds because the Walker Pond watershed has a complex cover and samples were taken several hundred yards below the cropped and pasture area.

## CONCLUSIONS

The quality of streamflow from the complex rural-agricultural watersheds in the Coastal Plain is good, a conclusion based on comparing the characteristics measured in this study with the standards set by the U.S. Public Health Service. Only iron concentrations exceeded the maximum acceptable value at certain times during the year. The quality should remain good if Coastal Plain agriculture remains diversified. The pastureland and pinegrass, hardwood-pine, and swamp-hardwood communities that comprise a significant portion of these rural-agricultural watersheds undoubtedly are in part responsible for the quality of runoff.

The survey showed that conductivity, chloride, total nitrogen, total phosphorus, and chemical oxygen demand were higher in streamflow from suburban-urban and agricultural watersheds with *definite* urban influence than in streamflow from rural-agricultural watersheds and rural-agricultural watersheds with *some* urban influence. Measured ranges of concentrations on these two broad classes of watersheds are shown in table 2.

Urban streamflow was diluted sufficiently by agricultural streamflow to significantly improve water quality.

Water quality gradually deteriorated when the population density exceeded a certain level, which changed seasonally as the discharge varied. The concentrations of the water characteristics in the streamflow from suburban-urban and agricultural areas with *definite* urban influence varied with seasonal fluctuations in runoff. This seasonal effect was not observed in streamflow from rural-agricultural areas.

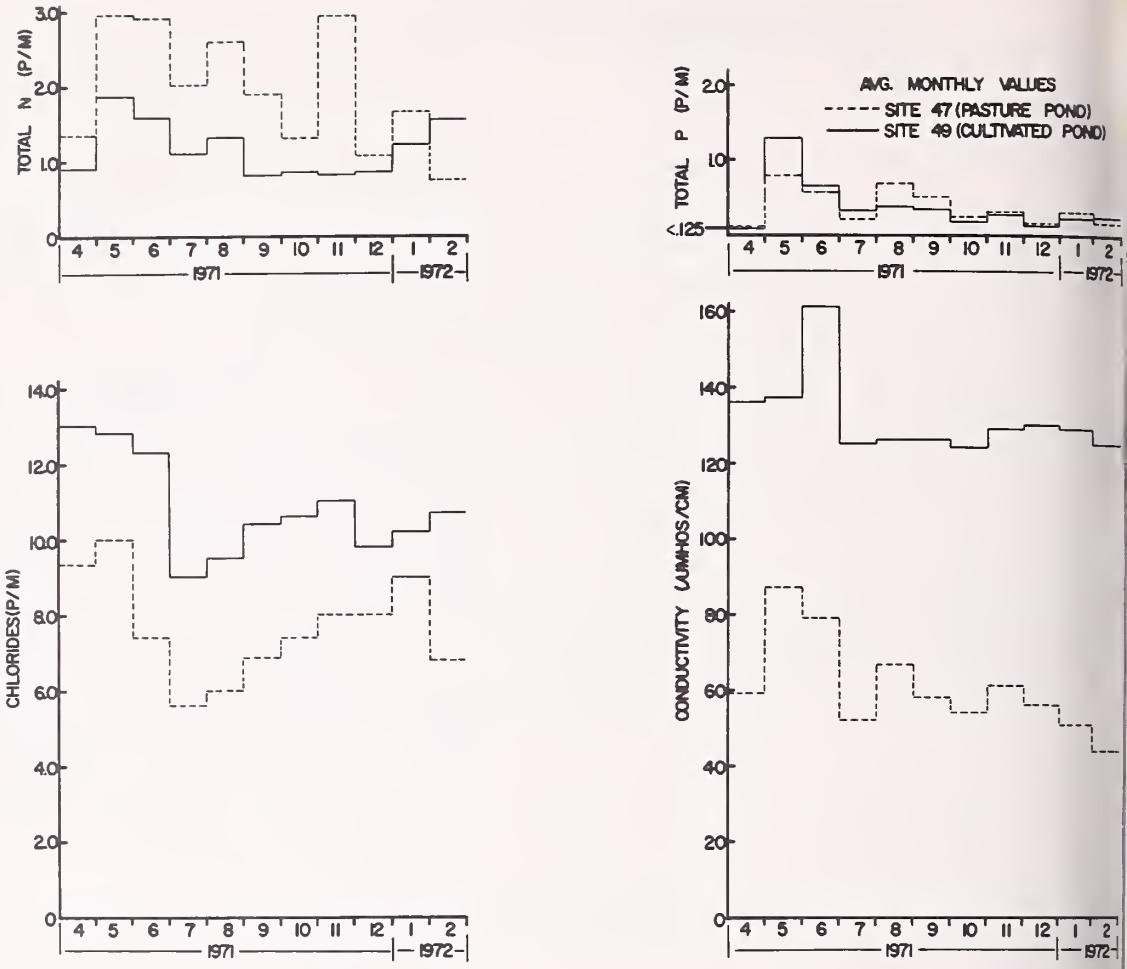



FIGURE 23.—Water quality characteristics of Hardy Ponds, draining intensively farmed watersheds.

TABLE 2.—*Maximum and minimum concentrations of observed characteristics from watersheds selected to compare seasonal effects on runoff water quality (Little River and New River–Withlacoochee) and U.S. Public Health Service standards*

| Characteristic | Rural-agricultural watersheds[1] | Suburban-urban watersheds[2] | U.S. Public Health Service standards[3] |
|---|---|---|---|
| Chlorides ..... p/m.... | 2–10 | 7–180 | 540 |
| Phosphorus ..... p/m.... | <0.12 | 0.12–7.0 | ([4]) |
| Conductivity ..... µ mhos/cm.... | 20–70 | 60–1,200 | [5]1,660 |
| Nitrogen ..... p/m.... | 0.25–1.5 | 0.75–10.5 | [6]23 |
| Chemical oxygen demand ..... p/m.... | 15–55 | 20–90 | ([4]) |
| Iron ..... p/m.... | 0.5–10.0 | 0.7–5.7 | 1.3 |
| pH ..... | 5.1–6.9 | 3.6–8.4 | 6.8–7.2 |

[1] Includes agricultural watersheds with *some* urban influence.

[2] Includes agricultural watersheds with *definite* urban influence.

[3] Maximum drinking water values. Source: Todd, David K. 1970. The water encyclopedia. Water Information Center, Manhassett Isle, Port Washington, N. Y.

[4] Value not available from U. S. Public Health Service.

[5] Specific conductance (µmhos). [6] Nitrates.

## APPENDIX.—WATER QUALITY STUDY SITES AND SAMPLING HISTORY, GEORGIA COASTAL PLAIN

| Site No. | Site location | Code[1] | Sampling date Start | Sampling date Stop | Sampling[2] | Total channel length (mi) | W.S. area (mi²) | Est. pop. Total | Est. pop. Per mi² |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Little River: Hwy. 37, west of Adel | B | 12–16–70 | 2– 7–72 | 1 | 300 | 422 | 25,320 | 60 |
| 2 | Little River: Hwy. 122, west of Hahira | B | 12–16–70 | 7–27–71 | 1 | 412 | 630 | 34,650 | 55 |
| 3 | Little River: Hwy. 94, west of Valdosta | B | 12–16–70 | 2– 7–72 | 1 | 428 | 710 | 39,050 | 55 |
| 4 | Withlacoochee: Hwy. 94, west of Valdosta | C | 12–16–70 | 2– 7–72 | 1 | 294 | 583 | 72,875 | 125 |
| 5 | Withlacoochee: Hwy. 84, west of Valdosta | B | 12–16–70 | 2– 7–72 | 1 | 748 | 1,354 | 115,090 | 85 |
| 6 | Withlacoochee: Hwy. 41, north of Valdosta | C | 12–16–70 | 10–26–71 | 1 | 282 | 562 | 44,800 | 80 |
| 7 | Withlacoochee: Hwy. 37, east of Adel | C | 12–16–70 | 2– 7–72 | 1 | 190 | 330 | 28,050 | 85 |
| 8 | New River: east of Lenox County Rd. | C | 12–16–70 | 2– 7–72 | 1 | 54 | 80 | 17,600 | 220 |
| 9 | Airport Pond: Tifton Airport | D | 12–16–70 | 12–16–70 | 1 | ... | 1 | 1,000 | 1,000 |
| 10 | New River: Hwy. 82, East Bridge | D | 12–16–70 | 2– 7–72 | 1 | 3 | 8 | 9,600 | 1,200 |
| 11 | New River: Hwy. 319, South Bridge | D | 12–16–70 | 2– 7–72 | 1 | 2 | 5 | 9,000 | 1,800 |
| 12 | Sewer outflow: Tifton city sewer (bridge) | D | 12–16–70 | 1–15–71 | 1 | 1 | 3 | 12,000 | 4,000 |
| 13 | Little River: Hwy. 319, south (2d bridge) | B | 12–16–70 | 8–17–71 | 1 | 83 | 153 | 8,415 | 55 |
| 14 | Arnold Creek: Hwy. 319, 1 mi south of Little River | A | 12–21–70 | 7–27–71 | 1 | 6 | 13 | 650 | 50 |
| 15 | Ty Ty Creek: Hwy. 319, south of Omega | A | 12–21–70 | 8–31–71 | 1 | 44 | 91 | 4,550 | 50 |
| 16 | Warrior Creek: Hwy. 319, south of Crosland (2d bridge) | B | 12–21–70 | 8–31–71 | 1 | 86 | 163 | 8,965 | 55 |
| 17 | Warrior Creek: south of Sylvester | B | 12–21–70 | 8–31–71 | 1 | 14 | 31 | 930 | 30 |
| 18 | Town Creek: 2 mi south of Sylvester | D | 12–21–70 | 8–31–71 | 1 | 6 | 13 | 9,425 | 725 |
| 19 | Town Creek: Hwy. 82, east of Sylvester | A | 12–21–70 | 8–31–71 | 1 | 2 | 5 | 250 | 50 |
| 20 | Flint River: Hwy. 32 | B | 12–21–70 | 8–11–71 | 1 | 377 | 3,916 | 391,600 | 100 |
| 21 | Jones Creek: 4 mi north of Hwy. 32 | A | 12–21–70 | 8–11–71 | 1 | 18 | 51 | 1,020 | 20 |
| 22 | 1st Creek west of Ashburn, Hwy. 112 | A | 12–21–70 | 8–31–71 | 1 | 2 | 3 | 120 | 40 |
| 23 | Ashburn Cr: 1st dirt road below Hwy. 112 | D | 12–21–70 | 8–31–71 | 1 | 3 | 6 | 210 | 35 |
| 24 | Hat Creek: east of Folsom Construction Co. | D | 12–21–70 | 8–31–71 | 1 | 1 | 3 | 4,500 | 1,500 |
| 25 | Deep Creek: Hwy. 112, east of Ashburn | A | 12–22–70 | 8–31–71 | 1 | 58 | 131 | 3,275 | 25 |
| 26 | Little Sand Creek: Hwy. 32, ½ mi west of Irwin County line | A | 12–22–70 | 8–31–71 | 1 | 4 | 8 | 125 | 16 |
| 27 | Alapaha River: Hwy. 32, west of Irwinville | B | 12–22–70 | 8–31–71 | 1 | 225 | 510 | 10,200 | 20 |
| 28 | Stump Creek: Hwy. 32, west of Ocilla | A | 12–22–70 | 8–11–71 | 1 | 3 | 8 | 400 | 50 |
| 29 | Stump Creek: Hwy. 129, south of Ocilla | D | 12–22–70 | 8–11–71 | 1 | 4 | 13 | 3,900 | 300 |
| 30 | Alapaha River: Hwy. 319, at bridge | C | 12–22–70 | 8–31–71 | 1 | 290 | 650 | 19,500 | 30 |
| 31 | Little River: Sta. M | A | 12–14–70 | 2– 7–72 | 2 | 2 | 8 | 160 | 20 |
| 32 | Little River: Sta. J | A | 12–14–70 | 9– 7–71 | 2 | 4 | 9 | 225 | 25 |
| 33 | Newell Branch: Sta. K | A | 12–14–70 | 2– 7–72 | 2 | 5 | 10 | 250 | 25 |
| 34 | Little River: Sta. I | A | 12–14–70 | 2– 7–72 | 2 | 11 | 22 | 550 | 25 |
| 35 | Little River: Sta. F | A | 11– 2–70 | 2– 7–72 | 2 | 24 | 48 | 1,680 | 35 |
| 36 | Little River: Sta. N | A | 11– 2–70 | 9– 7–71 | 1 | 2 | 6 | 300 | 50 |
| 37 | Little River: Sta. O | A | 10–26–70 | 9– 7–71 | 1 | 3 | 6 | 330 | 55 |
| 38 | Little River: Sta. B | A | 10–26–70 | 2– 7–72 | 2 | 67 | 126 | 4,410 | 35 |
| 39 | Sta. B pit site, northwest of Sta. B | A | 10–26–70 | 1– 5–71 | 1 | 0 | .0008 | 0 | 0 |
| 40 | New River: Sta. UR | B | 11– 2–70 | 2– 7–72 | 2 | 1.5 | 3 | 6,000 | 2,000 |

## APPENDIX.—WATER QUALITY STUDY SITES AND SAMPLING HISTORY, GEORGIA COASTAL PLAIN (Continued)

| Site No. | Site location | Code[1] | Sampling date Start | Sampling date Stop | Sampling[2] | Total channel length (mi) | W.S. area (mi²) | Est. pop. Total | Est. pop. Per mi² |
|---|---|---|---|---|---|---|---|---|---|
| 41 | New River: GW well at Sta. UR | C | 11- 2-70 | 2- 7-72 | 2 | 2 | 3 | 6,000 | 2,000 |
| 42 | Lake Mary (pond stage): Sta. Y | C | 11- 2-70 | 2- 7-72 | 2 | .75 | .11 | 220 | 2,000 |
| 43 | Lake Mary (inflow) | C | 11- 2-70 | 2- 7-72 | 2 | .5 | .08 | 198 | 1,800 |
| 44 | Lake Mary (outflow) | C | 11- 2-70 | 2- 7-72 | 2 | .75 | .11 | 220 | 2,000 |
| 45 | Walker Pond (pond stage) | A | 11- 2-70 | 2- 7-72 | 2 | .75 | .09 | 0 | 0 |
| 46 | Lindsey Pit | A | 11- 2-70 | 9- 7-71 | 2 | 0 | .01 | 0 | 0 |
| 47 | Hardy Pond (pasture) | A | 12-14-70 | 2- 7-72 | 2 | 0 | .01 | 0 | 0 |
| 48 | Hardy Pond (catfish) | A | 12-14-70 | 9- 7-71 | 2 | 0 | .07 | 0 | 0 |
| 49 | Hardy Pond (cultivated) | A | 4- 7-71 | 2- 7-72 | 2 | 0 | .04 | 0 | 0 |
| 50 | Water hole near Sta. I | A | 12-14-70 | 1- 5-71 | 1 | 0 | .0004 | 0 | 0 |
| 51 | Lake Drive Pond (near Lastinger Elementary) | D | 12-10-70 | 9- 7-71 | 2 | 0 | .003 | 12 | 4,000 |
| 52 | New River: Hwy. 319, North Bridge | C | 11-10-70 | 11-10-70 | ... | 2 | 5 | 9,000 | 1,800 |
| 53 | Watershed Office: Rainwater Rd. (ditch west of bldg.) | D | 10-26-70 | 9- 7-71 | 2 | .5 | .25 | 125 | 500 |
| 54 | Watershed Office: Culvert entrance northwest of bldg. | D | 11-10-70 | 9- 7-71 | 2 | .5 | .25 | 125 | 500 |
| 55 | Watershed Office: Culvert exit southwest of bldg. | D | 11-10-70 | 9- 7-71 | 2 | .5 | .25 | 125 | 500 |
| 56 | Little River: GW well at Sta. F | A | 1-11-71 | 2- 7-72 | 2 | 24 | 48 | 1,680 | 35 |
| 57 | Sta. Z | D | 1- 6-71 | 12-10-71 | (3) | 0 | .0013 | 0 | 0 |
| 58 | Fox Hill Creek: 1st creek south of Hwy. 82 | D | 1- 7-71 | 9- 7-71 | 1 | 4 | 3 | 2,250 | 750 |
| 59 | Stump Creek: South of city sewer lagoon (Ocilla) | D | 1-13-71 | 8-11-71 | 1 | 6 | 16 | 4,800 | 300 |
| 60 | Bussells Creek: Between Hwy. 319 and Union Rd., south of Tifton | D | 12-17-70 | 9- 7-71 | 2 | 2 | 5 | 6,000 | 1,200 |
| 61 | Sewer outflow: Tifton city sewer (culvert) | D | 1-15-71 | 2- 7-72 | 2 | 2 | 3.5 | 12,000 | 4,000 |
| 62 | One Mile Branch: Valdosta | D | 1-15-71 | 8-17-71 | 1 | 1 | 4 | 0 | 0 |
| 63 | Sugar Creek: Valdosta | D | 1-15-71 | 8-17-71 | 1 | 0 | 3 | 0 | 0 |
| 64 | Sewer outflow: Valdosta, Bay St. | D | 1-15-71 | 8-17-71 | 1 | 0 | 10 | 0 | 0 |
| 65 | Withlacoochee River: Hwy. 31 at Ga.-Fla. line | B | 1-26-71 | 8-17-71 | 1 | 56 | 1,471 | 125,035 | 85 |
| 66 | Mill outflow: Owens-Illinois at Clyattville | D | 1-26-71 | 2-18-71 | 1 | 0 | 0 | 0 | 0 |
| 67 | Knights Creek: Hwy. 94, east of Valdosta | A | 1-26-71 | 8-17-71 | 1 | 6 | 10 | 3,000 | 300 |
| 68 | Knights Creek: Hwy. 221, east of Valdosta | A | 1-26-71 | 8-17-71 | 1 | 4 | 3 | 2,250 | 750 |
| 69 | Flint River: Hwy. 3, at Mitchell County line | B | 1-27-71 | 8-11-71 | 1 | 550 | 5,060 | 632,500 | 125 |
| 70 | Willacoochee: Between Ocilla and Fitzgerald | C | 1-27-71 | 8-11-71 | 1 | 15 | 45 | 9,900 | 220 |
| 71 | Ocmulgee River: Hwy. 441, south of Jacksonville | B | 1-27-71 | 8-11-71 | 1 | 400 | 3,750 | 375,000 | 100 |
| 72 | Tifton Industrial Outflow: Hwy. 125 | D | 2- 8-71 | 8-17-71 | 1 | 2 | 3 | 1,350 | 450 |
| 73 | Creek south of Fitzgerald: Hwy. 319 (north of country club) | B | 2-10-71 | 8-11-71 | 1 | 1 | 7 | 9,100 | 1,300 |
| 74 | Hwy. above Reed Bingham State Park | A | 2-18-71 | 8-17-71 | 1 | 288 | 375 | 22,500 | 60 |
| 75 | New River County Rd. between Hwys. 82 and 125 | C | 2-18-71 | 2- 7-72 | 1 | 5 | 15 | 11,250 | 750 |
| 76 | Dry Creek: South of Albany | C | 2-23-71 | 8-11-71 | 1 | 20 | 65 | 3,900 | 60 |
| 77 | Abrams Creek: Hwy. 257 | A | 4-15-71 | 8-11-71 | 1 | 37 | 76 | 1,520 | 20 |
| 78 | Mill Creek: Hwy. 257 | A | 4-15-71 | 8-11-71 | 1 | 36 | 56 | 1,400 | 25 |
| 79 | Sta. W | D | 4-30-71 | 12-10-71 | (3) | 0 | .001 | 0 | 0 |
| 80 | New River: Ferry Lake Rd. | C | 7-13-71 | 2- 7-72 | 2 | 2.5 | 4 | 8,000 | 2,000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 81 | Hardy Pond (pasture) outflow | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .024 | 0 | 0 |
| 82 | Hardy Pond (pacture) : Weir A (emergency) | A | | | 1 | 0 | .024 | 0 | 0 |
| 83 | Hardy Pond (pasture) : Weir B | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .008 | 0 | 0 |
| 84 | Hardy Pond (pasture) : Weir C | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .008 | 0 | 0 |
| 85 | Hardy Pond (catfish pond) | A | 8– 3–71 | 8– 3–71 | 1 | 0 | .054 | 0 | 0 |
| 86 | Hardy Pond (cultivated) outflow | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .045 | 0 | 0 |
| 87 | Hardy Pond (cultivated) : Weir A | A | | | 2 | 0 | .015 | 0 | 0 |
| 88 | Hardy Pond (cultivated) : Weir B | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .025 | 0 | 0 |
| 89 | Hardy Pond (cultivated) : Weir C (emergency) | A | | | 1 | 0 | .045 | 0 | 0 |
| 90 | Walker Pond (outflow) | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .112 | 0 | 0 |
| 91 | Walker Pond: Weir A | A | 8–16–71 | 2– 7–72 | 2 | 0 | .030 | 0 | 0 |
| 92 | Walker Pond: Weir B | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .055 | 0 | 0 |
| 93 | Walker Pond: Weir C | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .025 | 0 | 0 |
| 94 | New River: Hwy. 125 at Berrien County line | C | 8–17–71 | 2– 7–72 | 1 | 26 | 44 | 15,400 | 350 |
| 95 | Middle Creek: Lower Brookfield Rd. | A | 8–17–71 | 2– 7–72 | 1 | 7 | 15 | 2,250 | 150 |
| 96 | Middle Creek: Hwy. 319 north | A | 8–17–71 | 2– 7–72 | 1 | 2.5 | 7 | 1,750 | 250 |

[1] Watershed classification code. A=rural-agricultural. B=rural-agricultural with *some* urban influence. C=rural-agricultural with *definite* urban influence, D=urban-suburban.

[2] 1=sample taken every other week or every third week. 2=weekly sampling.

[3] Samples taken daily.

[5] Specific conductance ($\mu$mhos). [6] Nitrates.

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## APPENDIX.—WATER QUALITY STUDY SITES AND SAMPLING HISTORY, GEORGIA COASTAL PLAIN (Continued)

| Site No. | Site location | Code[1] | Sampling date Start | Sampling date Stop | Sampling[2] | Total channel length (mi) | W.S. area (mi²) | Est. pop. Total | Est. pop. Per mi² |
|---|---|---|---|---|---|---|---|---|---|
| 81 | Hardy Pond (pasture) outflow | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .024 | 0 | 0 |
| 82 | Hardy Pond (pacture): Weir A (emergency) | A | | | 1 | 0 | .024 | 0 | 0 |
| 83 | Hardy Pond (pasture): Weir B | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .008 | 0 | 0 |
| 84 | Hardy Pond (pasture): Weir C | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .008 | 0 | 0 |
| 85 | Hardy Pond (catfish pond) | A | 8– 3–71 | 8– 3–71 | 1 | 0 | .054 | 0 | 0 |
| 86 | Hardy Pond (cultivated) outflow | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .045 | 0 | 0 |
| 87 | Hardy Pond (cultivated): Weir A | A | | | 2 | 0 | .015 | 0 | 0 |
| 88 | Hardy Pond (cultivated): Weir B | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .025 | 0 | 0 |
| 89 | Hardy Pond (cultivated): Weir C (emergency) | A | | | 1 | 0 | .045 | 0 | 0 |
| 90 | Walker Pond (outflow) | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .112 | 0 | 0 |
| 91 | Walker Pond: Weir A | A | 8–16–71 | 2– 7–72 | 2 | 0 | .030 | 0 | 0 |
| 92 | Walker Pond: Weir B | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .055 | 0 | 0 |
| 93 | Walker Pond: Weir C | A | 8– 3–71 | 2– 7–72 | 2 | 0 | .025 | 0 | 0 |
| 94 | New River: Hwy. 125 at Berrien County line | C | 8–17–71 | 2– 7–72 | 1 | 26 | 44 | 15,400 | 350 |
| 95 | Middle Creek: Lower Brookfield Rd. | A | 8–17–71 | 2– 7–72 | 1 | 7 | 15 | 2,250 | 150 |
| 96 | Middle Creek: Hwy. 319 north | A | 8–17–71 | 2– 7–72 | 1 | 2.5 | 7 | 1,750 | 250 |

[1] Watershed classification code. A=rural-agricultural. B=rural-agricultural with *some* urban influence. C=rural-agricultural with *definite* urban influence, D=urban-suburban.

[2] 1=sample taken every other week or every third week. 2=weekly sampling.

[3] Samples taken daily.

[5] Specific conductance (μmhos). [6] Nitrates.

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